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Application of Environment Assessment related to GIZ ECO Micro Hydropower Plants in the Sidama Zone/Ethiopia

DIPLOMARBEIT

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Erklärung

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Heidelberg, 10. November 2011

Katharina Meder

Abstract

The German International Cooperation Energy Coordination Office (GIZ ECO) Ethiopia initiated a project on off-grid rural electrification in order to improve sustainable energy access, to combat current energy-related problems and hence contribute to reaching the UN Millennium Development Goals (MDGs). Four pilot micro hydropower (MHP) plants have been installed in southern Ethiopian villages. Within the scope of the GIZ ECO project, best practice manuals are being developed in order to be able to easily promote the MHP technology nationwide in the future. Since GIZ ECO recognized that environmental issues are crucial for the sustainable use of the MHP plants a manual on environment assessment (EA) and watershed action planning (WAP) was prepared in order to include environmental issues in each future MHP implementation. The work objectives presented in the study on hand were to develop the aforementioned manual on EA and WAP and to test its applicability, particularly focusing on EA, using the catchment areas of the GIZ ECO's MHP pilot projects Gobecho I and II as well as Hagara Sodicha in the Sidama zone/SNNPR/Ethiopia.

The manual's development included methods such as expert interviews, site visits and literature review whereas its application in the MHP plants' catchments drew upon methods such as GPS-based ground check, GIS-based land use mapping as well as interviews with local farmers.

The manual's application in the catchments of the MHP plants Gobecho I and II as well as Hagara Sodicha showed that the two catchments feature both positive, but primarily negative land use practices as well as various associated degradation features to a different degree and extent. In terms of land use and prevailing degradation causes and features, similarities were detected between the respective downstream parts of the catchments as well as between the upstream parts of the catchments. Downstream parts are characterized by agriculture and prevailing problems identified are hillside encroachment and landslides whereas upstream parts feature extensive grazing areas and major problems are overgrazing and cattle step. Accordingly, appropriate mitigation techniques and land use recommendations were identified for each catchment subdivision in order to increase the sustainability of land use and thus the MHP plants. In the downstream areas the latter primarily include reforestation and the installation of soil bunds and bench terraces whereas the implementation of fencing and the establishment of grazing plans are recommended for the upstream catchments.

Zusammenfassung

Das Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH Energy Coordination Office (GIZ ECO) Äthiopien hat ein Projekt zur ländlichen Elektrifizierung initiiert, das das Ziel verfolgt, den nachhaltigen Zugang zu Energien zu verbessern, energiebezogene Probleme zu bekämpfen und somit zur Erreichung der UN Millenniums Entwicklungsziele beizutragen. Vier Pilotkleinwasserkraftwerke wurden im Zuge dessen in südäthiopischen Dörfern installiert. Des Weiteren werden im Rahmen des GIZ ECO Projekts verschiedene Best Practice Manuals entwickelt, um die Kleinwasserkrafttechnologie zukünftig auch landesweit fördern zu können. Da GIZ ECO erkannt hat, dass ökologische Faktoren die Nachhaltigkeit der Kleinwasserkraftwerke maßgeblich beeinflussen, wurde ein Manual zum Thema „Environment Assessment (EA) and Watershed Action Planning (WAP)“ entwickelt, um den Einbezug von Umweltthematiken bei allen zukünftigen Kleinwasserkraftwerkinstallationen zu gewährleisten. Das Ziel der vorliegenden Studie war das EA und WAP Manual zu entwickeln und seine Anwendbarkeit anhand der Wassereinzugsgebiete der GIZ ECO Pilotkleinwasserkraftwerke Gobecho I und II sowie Hagara Sodicha in der Sidama Zone/SNNPR/Äthiopien zu testen. Hierbei lag der Fokus vor allem auf dem „environment assessment“ Teil des Manuals.

Die Entwicklung des Manuals beinhaltete Methoden wie z.B. Experteninterviews, Projektbesuche und Literaturauswertung wohingegen die Anwendung in den Wassereinzugsgebieten der Kleinwasserkraftwerke auf GPS-basierten Feldaufenthalten, GIS-basierter Landnutzungskartierung sowie Interviews mit lokalen Bauern beruhte.

Die Anwendung des Manuals in den Wassereinzugsgebieten der Kleinwasserkraftanlagen Gobecho I und II sowie Hagara Sodicha hat gezeigt, dass die zwei Einzugsgebiete positive aber vor allem auch negative Landnutzungsformen aufweisen, die mit verschiedenen Degradationsformen in unterschiedlichem Ausmaß einhergehen. Bezogen auf Landnutzung und vorherrschende Degradationsursachen und –formen wurden Gemeinsamkeiten zwischen den jeweiligen Ober- und Unterläufen der Wassereinzugsgebiete festgestellt. Die Unterläufe beider Einzugsgebiete zeichnen sich durch intensive landwirtschaftliche Nutzung aus. Identifizierte Probleme sind die übermäßige ackerbauliche Nutzung von Hangbereichen sowie Hangrutschungen. Die Oberläufe sind dem hingegen durch weitläufige Weideflächen und damit einhergehend durch Überweidung und dem Auftreten von Viehtritt charakterisiert. Dementsprechend wurden für jeden Teil der Wassereinzugsgebiete angemessene Gegenmaßnahmen und Landnutzungsempfehlungen herausgearbeitet, um die Nachhaltigkeit der Landnutzung und somit der Kleinwasserkraftnutzung zu gewährleisten. In den Unterläufen beider Gebiete beinhaltet dies vor allem Wiederaufforstung sowie die Anlage von Terrassen, wohingegen die Empfehlungen für die Oberläufe vor allem die Anlage von Zäunen und die Etablierung eines Weideplans beinhalten.

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List of acronyms

AMES-E	- Access to Modern Energy Services Ethiopia
AWMISET	- Agricultural Water Management Information System of Ethiopia
BMZ	- German Ministry for Economic Cooperation and Development
DED	- Deutscher Entwicklungsdienst
DEM	- Digital Elevation Model
DGIS	- Dutch Directorate-General for International Cooperation
EA	- Environment Assessment
ECO	- Energy coordination office
EEA	- Ethiopian Electric Agency
EECMY	- Ethiopian Evangelical Church Mekane Yesus
EEPCo	- Ethiopian Electric Power Cooperation
EIA	- Environmental Impact Assessment
EnDev	- Energising Development
EPA	- Environmental Protection Agency
EREDPC	- Ethiopian Alternative Energy Development Promotion Center
FAO	- Food and Agriculture Organization
GIZ	- Deutsche Gesellschaft für International Zusammenarbeit GmbH (German International Cooperation)
GIS	- Geographical Information System
GPS	- Global Positioning System
GTP	- Growth and Transformation Plan
GTZ	- Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (German Technical Cooperation)
HV	- high voltage
ICS	- Interconnected system
InWent	- Internationale Weiterbildung und Entwicklung
ILRI	- International Livestock Research Institute
ITCZ	- Intertropical convergence zone
LV	- low voltage
MDG	- Millennium Development Goal
MHP	- micro hydropower
PHP	- pico hydropower
PV	- photovoltaic
REF	- Rural Electrification Fund
REES	- Rural Electrification Executive Secretary
SCS	- self-contained system
SNNPR	- Southern Nations, Nationalities, and People's Republic
SHS	- Solar home system
SLM	- Sustainable Land Management
SWH	- solar water heating
TERNA	- Technical Expertise for Renewable Energy Application
UEAP	- Universal Electrification Access Program

UN	- United Nations
WAP	- Watershed Action Planning
WFP	- World Food Program
WGS	- World Geodetic System

1. Introduction and research objectives

The sustainable use of micro hydropower (MHP) plants is highly dependent on the environmental condition of the plants' catchment areas. Since degradation might decrease the retention capacity of the soil, the discharge might be altered and thus the occurrence of the river drying out or flash flood events may increase. Furthermore degradation might amplify the sediment load of the rivers. All of this negatively affects the sustainable use of MHP plants, since without a continuous discharge, sufficient and sustainable electricity supply cannot be provided. Increased sediment load will moreover wear off the plants' turbines and thus reduce the durability of its equipment (see fig. 1). In order to provide for sustainable land use and hence sustainable electricity supply, it is of great importance to manage the catchment carefully (see Annex 1).

Relation between catchment degradation and MHP use

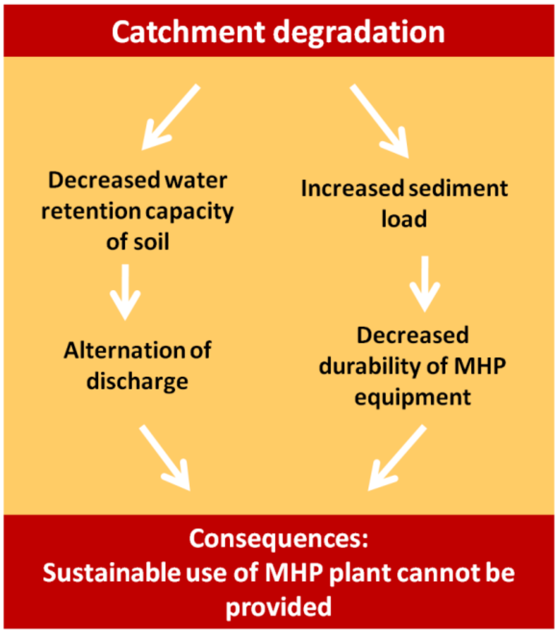

Fig. 1: (Simplified) relation between catchment degradation and MHP use.

Source: Meder 2011.

In order to improve sustainable energy access, to combat current energy-related problems such as environmental degradation, health matters and alike and thus to contribute to reaching the UN Millennium Development Goals (MDGs), the German International Cooperation Energy Coordination Office (GIZ ECO) Ethiopia works with the Ethiopian government in the field of renewable energies and micro hydropower in particular. In line with the installation of four pilot MHP plants in the Sidama zone/Southern Nations, Nationalities, and People's Region (SNNPR)/Ethiopia and in order to be able to easily distribute the technology nationwide in the future, best practices in form of manuals were developed. GIZ ECO recognized that environmental sustainability is crucial for the sustainable use of the MHP plants and thus a manual on environment assessment (EA) and

watershed action planning (WAP) was prepared in order to include environmental issues in each future MHP implementation.

The objectives of the research presented in this paper were:

1. to **develop the manual on EA and WAP** (see Annex 1) and
2. to **test its applicability**, with **focus on the manual's EA approach**, using two catchment areas of the GIZ ECO's MHP pilot projects Gobecho I and II as well as Hagara Sodicha in the Sidama zone/SNNPR/Ethiopia as research sites (see fig. 2).

Location of GIZ ECO MHP plants' catchments in the Sidama zone/SNNPR/Ethiopia

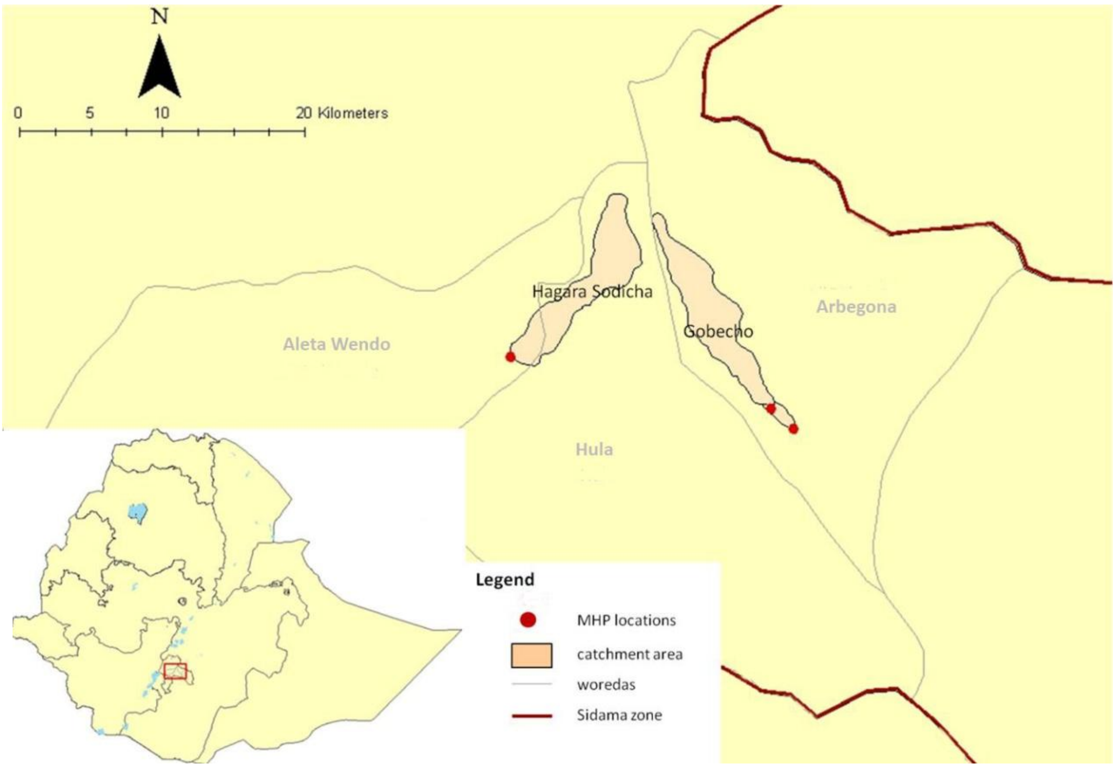

Fig. 2: Location of the GIZ ECO MHP plants' catchments in the Sidama zone/SNNPR/Ethiopia. Source: Meder 2011, derived from EGGER 2010 and MAPLIBRARY 2011.

The paper is structured as follows: In order to set the GIZ ECO MHP projects in the context of the Ethiopian energy situation and associated problems, the latter will be presented in chapter 2 while taking into account the Ethiopian electricity sector as well as the current use and potentials of renewable energies in Ethiopia, particularly focusing on hydropower and MHP respectively. Chapter 3 will give an introduction to the GIZ ECO and will depict its MHP projects and their socio-economic and environmental impacts before chapter 4 gives a general overview and introduction to the wider research area. Chapter 5 elaborates on the methods used for the research presented in this paper. Then the EA and

WAP manual will be depicted in chapter 6 before the actual research results from the two MHP catchments will be presented and discussed in chapter 7 and 8 respectively. Finally, recommendations will be given and a conclusion will be drawn in chapter 9 and 10.

2. Energy situation in Ethiopia

Ethiopia, ranked 157th on the 2010 Human Development Index, is one of the least developed countries in the world (UNDP 2010a). With a GDP of 991 US$ per capita and an average annual income of 120 US$ per capita, approximately 40% of its 85 million inhabitants live below the poverty line (UNDP 2010b; FENGLER, FENGLER 2007). Ethiopia has one of the lowest rates of access to modern energy services, its energy supply is primarily based on biomass (HATHAWAY 2008). According to the World Bank only an estimated 12% of the Ethiopian population has access to electricity[1] (WORLD BANK 2008). With almost 85% of the Ethiopians living in rural areas, there is a significant bias between the power supply of urban and rural population: only 2% of the rural but 86% of the urban residents has access to electricity (UN DATA 2007; HATHAWAY 2008). With a share of 92.4% of Ethiopia's energy supply, waste and biomass are the country's primary energy sources, followed by oil (6.7%) and hydropower (0.9%) (IEA 2008) (see fig. 3).

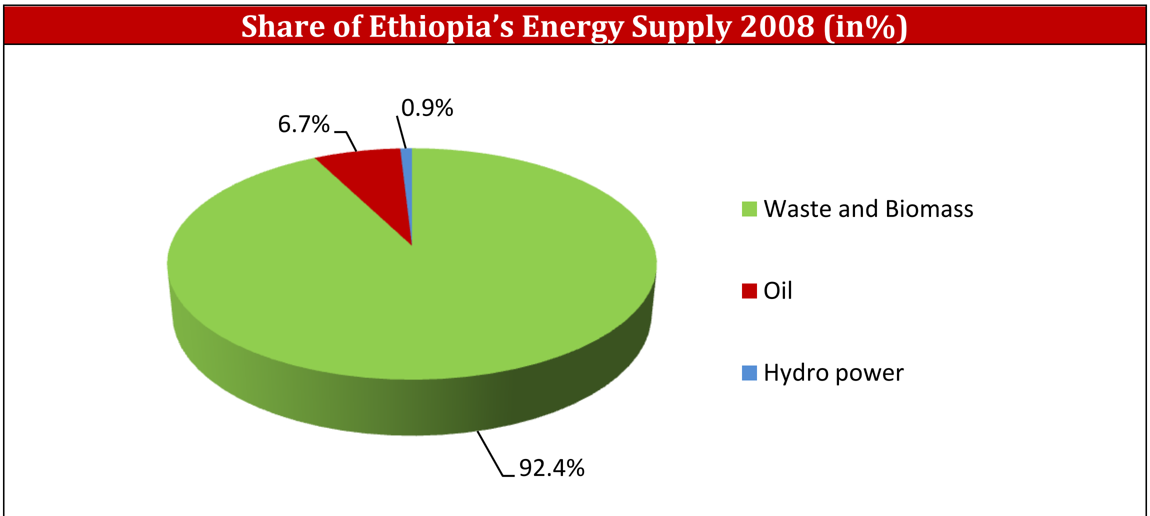

Fig. 3: Share of Ethiopia's energy supply 2008 (in %). Source: Meder 2011, derived from IEA 2008.

Most of the traditional energy production is used for cooking. In rural areas 85% of people depend on wood as their main energy source. The use of biomass for energy production is not only inefficient but can have negative effects on people's health. Smoke emission resulting from indoor cooking can lead to various respiratory diseases and goes along with

[1] Contrary to the 12% mentioned in the cited 2008 Word Bank report, EEPCo (Ethiopian Electric Power Cooperation) uses a figure of 41% current "electric energy access". EEPCo bases this figure on the number of people within the reach of low-voltage distribution lines, not the actual number of directly connected people (ETHIO RESOURCE GROUP 2009). For total number of EEPCo customers and connected towns and villages see fig. 5.

a high risk of fire. Furthermore, women and children spend up to 6 hours per day collecting and carrying firewood which can result in physical impairments such as postural deformities. Additionally the women are not only frequently harassed by border guards bribing them for money, but also they are prey to sexual assault which puts them at high HIV/AIDS risk (Bölli, Feibel 2008; World Bank undated). Moreover, this time could be used for education. Energy production based on biomass also negatively affects the environment. Only 3.56% of Ethiopia's natural forest cover still exists, the annual depletion rate is estimated to be 150,000 to 200,000 ha (Convention on Biological Diversity undated). The destruction of natural vegetation due to wood based energy consumption can lead to soil degradation, erosion and thus to decreased water levels of rivers and reduced recharge rates of aquifers (Hathaway 2008). Moreover, the use of animal dung for energy production leads to a removal of nutrients from cropland and thus to a decrease of agricultural productivity (Bölli, Feibel 2008; Mekonnen, Köhlin 2008).

2.1 Ethiopian Electricity Sector

According to the Ethiopian Electric Power Corporation (EEPCo), Ethiopia's total electricity generation in 2010 was 3,981.07 GWh. Although hydropower contributes only 0.9% to the total energy supply, it generates 88% of electricity and is thus the country's dominating electricity resource, followed by Diesel (11%) and geothermal (1%) electricity generation (see fig. 4) (EEPCo 2011).

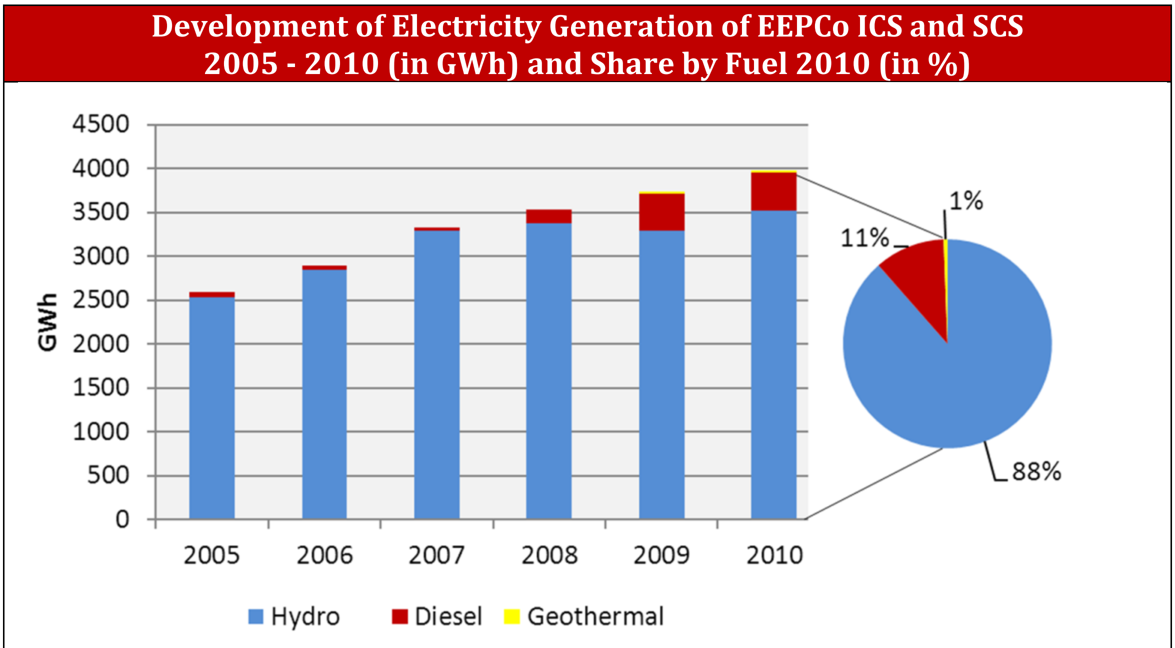

Fig. 4: Development of energy generation of EEPCo's ICS and SCS 2005 – 2010 (in GWh) and share by fuel in % (2010). Source: Meder 2011, derived from EEPCo 2011.

In the ICS (interconnected system) EEPCo currently operates 11, primarily large, hydropower-, one geothermal- and 15 diesel grid-connected power plants with a total capacity of 1842.6 MW, 7.3 MW and 172.3 MW respectively. Another three hydropower- and several diesel off-grid power plants with a capacity of 6.15 MW and 31.34 MW respectively operate as self-contained systems (SCS) (EEPCo 2011). The ICS is expanding whereas the SCS is shrinking due to the interconnection of previously SCS served towns to the ICS (ETHIO RESOURCE GROUP 2009). As of July 2010, a total of 5163 towns and villages and a total of 1,896,265 customers were connected to the ICS and SCS by EEPCo[2] (see fig. 5). Approx. 87% of customers are domestic, 12% commercial and 1.1% industrial whereas only 0.1% is used for street lightning (EEPCo 2011).

Number of ICS and SCS Customers and Towns/Villages connected by EEPCo as of July 2010

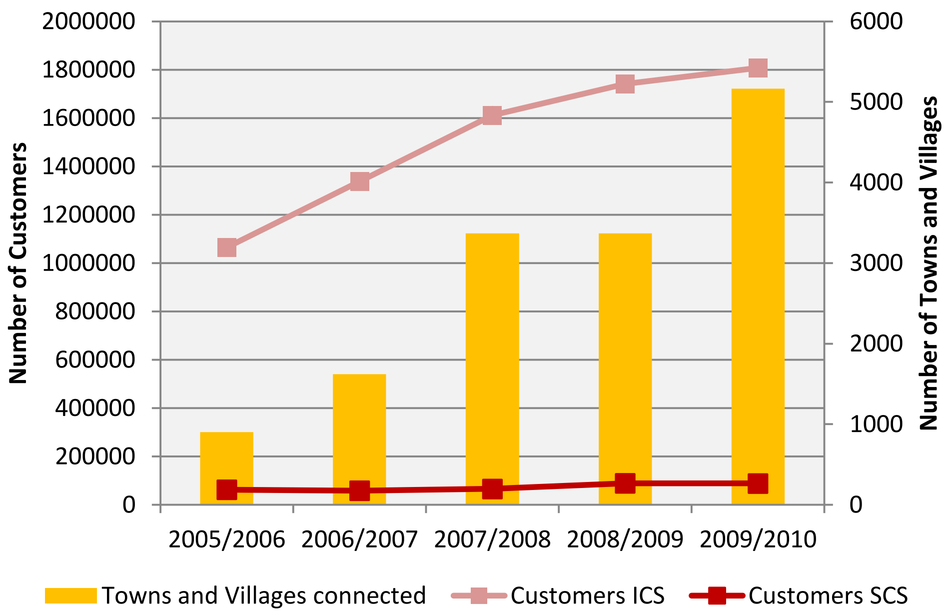

Fig. 5: Number of ICS and SCS customers and towns/villages connected by EEPCo as of July 2010. Source: Meder 2011, derived from EEPCo 2011.

In 2005 EEPCo launched the Universal Electrification Access Program (UEAP), with the goal to connect a total of 6878 towns and villages to the grid and to increase the energy generation capability to 6386 GWh by 2010. Although the aspired target was not fully met,

[2] As mentioned in footnote 1, EEPCo states that 41% of the population has "electric energy access". Contrary to this, the actual number of EEPCo customers is only 2% of the 75.8 Mio people that the company states as the current population of Ethiopia.

electricity generation increased 53% from 2,587.2 GWh in 2005 to 3,981.07 GWh in 2010 (EEPCo 2005; EEPCo 2011).

However, the production increase does not keep pace with the grid extension activities. Transmission lines increased from a total length of 8,003.93 km in 2006 to 10,884.24 km in 2010, distribution lines' total length even quadrupled from 33,000 km in 2005 to 126,038 km in 2010. Although electricity generation is steadily increasing this creates a bias between the grid extension and the load of power generated, which results in a shortage of electricity and thus frequent power cuts (see fig. 6). Furthermore, transmission and distribution losses of the ICS are high: 20% were lost in the period between 2001 and 2005. Due to the hence limited electricity service, people's willingness to pay might decrease significantly and makes more reliable power supply in isolated systems more attractive (EEPCo 2011; BÖLLI, FEIBEL 2008; ETHIO RESOURCE GROUP 2009).

Distribution lines (in km) and Power Generation (in GWh) 2004 – 2010

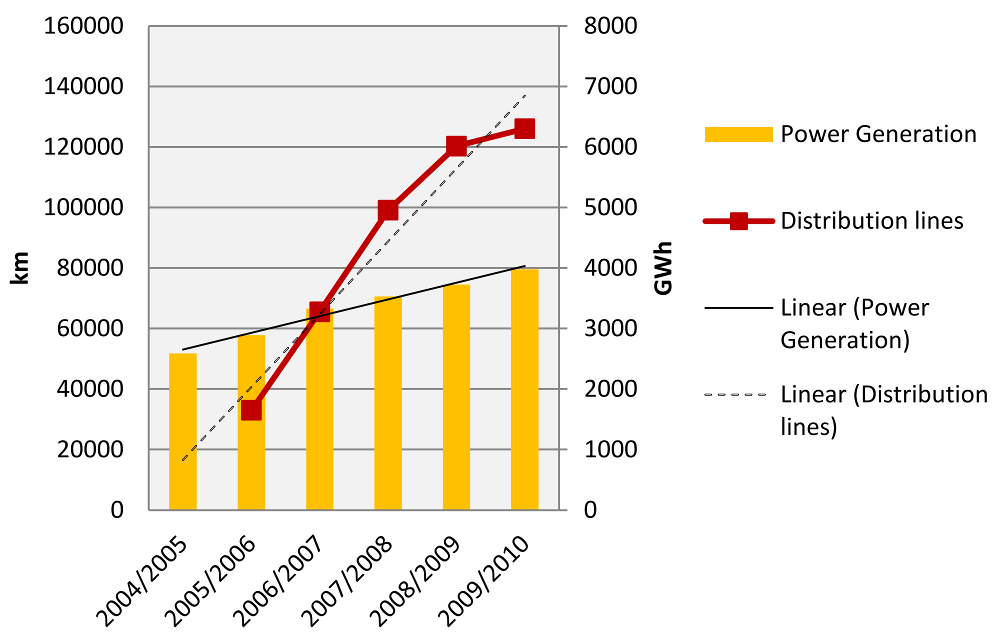

Fig. 6: Distribution lines (in km) and power generation (in GWh) 2004 - 2010. Source: Meder 2011, derived from EEPCo 2011.

In addition to EEPCo's ICS and SCS the Ethiopian government is furthermore promoting off-grid rural electrification through the Ethiopian Alternative Energy Development Promotion Center (EREDPC), which is the executive arm of the Rural Electrification Fund (REF). The program enables private and corporative engagement in rural electrification activities by providing loans and technical support to develop small decentralized systems which are connected to neither the ICS nor the SCS (ETHIO RESOURCE GROUP 2009, GROSS,

BÖLLI 2009). In order to assess and implement projects under the REF, EREDPC established the Rural Electrification Executive Secretary (REES) which is not just responsible for project appraisal but also for providing capacity building, advisory services and training to regional energy bureaus (GROSS, BÖLLI 2009). Not only the budget of the off-grid rural electrification program is much smaller than the one of the grid based program (less than 1% of the latter), also the program itself is not as progressive (ETHIO RESOURCE GROUP 2009). The current 5-year Growth and Transformation Plan (GTP), launched in 2010 and running until 2015, targets to increase Ethiopia's total generating capacity from 8,000 to 10,000 MW by 2015 (MoFED 2010). This would quadruple or even quintuple the country's current capacity of approximately 2000 MW. To this effect, the plan includes the installation of 8 large hydropower schemes (8737 MW total capacity), 7 wind plants (866 MW total capacity) and a 70 MW geothermal power plant (ETHIO RESOURCE GROUP 2011). The number of connected customers is planned to be more than doubled: the target is to connect 4 million customers by 2015 (compare fig 5) (MoFED 2010).

2.2 Renewable energy: current use and potential

Ethiopia has an enormous potential for renewable energies which is hardly exploited. As of August 2009, only 7% of the estimated 54 GW economically exploitable power generation resources was either developed or committed to be developed (ETHIO RESOURCE GROUP 2009). Major renewable resources for electricity generation are hydropower, wind and geothermal energy as well as photovoltaic (PV) and biogas.

2.2.1 Hydropower

Since Ethiopia uses a classification of hydropower systems which differs from other countries, the Ethiopian definitions as shown in table 1 are used throughout this paper.

Tab. 1: Ethiopian hydropower classification. Source: BÖLLI, FEIBEL 2008.

Terminology	Capacity limits	Unit
Large	>30	MW
Medium	10 – 30	MW
Small	1 – 10	MW
Mini	501 – 1,000	kW
Micro	11 - 500	kW
Pico	≤10	kW

It is estimated that Ethiopia`s hydropower potential with up to 45,000 MW is the 2nd highest in Africa (only DR. Congo has higher potential). Approximately 30,000 MW are estimated to be economically feasible which is equivalent to an electricity generation of 162 TWh (MINISTERIAL CONFERENCE ON WATER FOR AGRICULTURE AND ENERGY IN AFRICA 2008; BÖLLI, FEIBEL 2008). The current production of 3.98 TWh thus equals an exploitation of only 2.5%. In general, Ethiopia's terrain is advantageous for hydropower projects. A vast potential is not just given for large hydropower projects but also for small scale schemes, particularly in remote areas, which are not connected to the national grid. The total theoretical potential for micro hydropower schemes is 100 MW (EEA 2003).

2.2.1.1 Large hydropower

As mentioned above, (primarily large) hydropower plants contribute 88% to Ethiopia's current electricity generation and thus make hydropower the dominating energy resource. Benefits of hydropower utilization in Ethiopia are manifold. Hydropower is not just cheaper than renewable alternatives but also, as an indigenous resource, it secures the energy supply and decreases the dependency on energy imports. Furthermore large hydropower projects are usually multi-purpose projects with potential for irrigation and water regulation and can thus help to mitigate the impacts of extreme weather conditions such as drought and floods (ETHIO RESOURCE GROUP 2009). Nonetheless large hydropower projects are controversial, since they are associated with a number of negative environmental as well as socio-economic effects. Environmental impacts occur throughout

the river basin and affect not just quantity and quality of water resources, but also soils and biodiversity. The construction of large dams and associated civil structures can for example result in an alternation of water quantity in downstream areas, affecting long-established farming practices such as flood-dependent recession agriculture. Water quality and biodiversity can be decreased by increased erosion and thus sedimentation due to deforestation caused by construction work and resettlement (ETHIO RESOURCE GROUP 2009). Furthermore the plants' reservoirs produce a significant amount of greenhouse gases such as carbon dioxides and methane, in some cases emissions are found to be higher than from plants running from fossil fuels. This is because, due to the initial flooding of the reservoir, a large amount of carbon tied in vegetation is released when plants rot. Methane, on the other hand, builds up due to the anoxic decomposition of organic matter on the reservoirs' bottom (GRAHAM-ROW, 2005). Resettlement programs associated with the construction of large dams also have a variety of socio-economic impacts. People are often relocated to less suitable areas (steep terrain or less fertile soils) which does not only increase land degradation but also puts them at high impoverishment risk (CERNEA 2004). A further critical aspect associated with large hydropower projects is that costs and benefits do not necessarily accrue to the same group of people: local communities often have to bear high losses but do not benefit from the electricity supplied (ETHIO RESOURCE GROUP 2009). Moreover the high dependency on (large) hydropower projects for electricity generation increases the economy's vulnerability to drought (HATHAWAY 2008). The construction of large dams is cost intensive and thus the government's focus on large scale projects is likely to decrease the funding of small decentralized projects with less environmental impacts in rural areas.

2.2.1.2 Pico and micro hydropower

As mentioned above, the Ethiopian definition of hydropower schemes differ from the ones of other countries. Typically **pico hydropower (PHP)** plants have a capacity of up to 3 kW. They are characterized by the absence of a distribution grid and supply one or two households. Nonetheless the pico hydropower range in Ethiopia is extended up to 10 kW (see table 1) which makes sense considering that widely-used injera[3] cookers with capacities of up to 5 kW need to be supplied. Thus two households with one injera cooker each fully absorb the plant's capacity, without requiring a distribution network. Defining **micro hydropower (MHP)** schemes from a range between 11 – 500 kW, it makes sense to distinguish between a lower range (≤30 kW), supplying individual villages without high voltage (HV) transmission and an upper range (31 – 500 kW) for small towns or several villages which are interconnected by HV lines and a low voltage (LV) distribution grid (EEA 2003).

[3] Typical Ethiopian bread made of teff flour.

According to EEA (2003), the specific yield of Ethiopian highlands with a moisture surplus of at least 300 mm/a is 500 W/km^2 [4] (see fig. 7). Since the maximum of MHP schemes is defined with 500 kW, the largest catchment area for MHP development is thus 1,000 km^2. Subtracting the catchments >1,000 km^2 from the total of 315,000 km^2 with perennial flows and a respective moisture surplus, that leaves a land area of 200,000 km^2 suitable for MHP development. As mentioned above, Ethiopia has thus a theoretical MHP potential of 100 MW (EEA 2003; BÖLLI, FEIBEL 2008). Most promising sites can be found in the western part of the country, since suitable topographic conditions and constant flows are prevailing (GROSS, BÖLLI 2009) (see fig. 7). Taken the same data set as a basis for PHP development, a PHP catchment must at least have an area of 15 km^2. Since a catchment of that size is rarely available to individual farmers, PHP potential is rather limited and allows respective plants only in sparsely populated areas (BÖLLI, FEIBEL 2008).

Mean Annual Water Surplus in Ethiopia

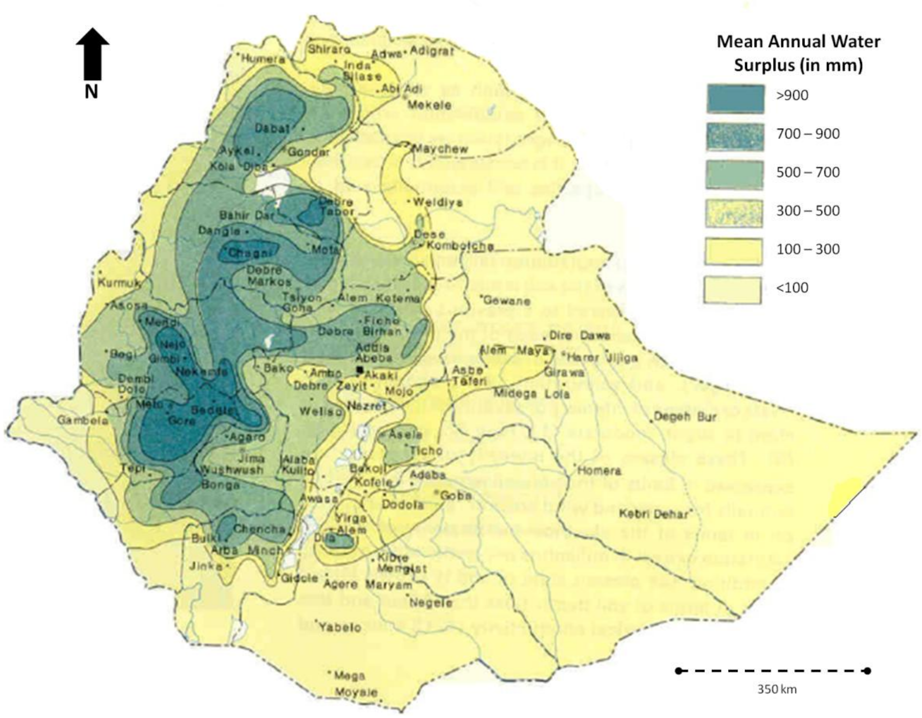

Fig. 7: Mean annual water surplus Ethiopia. Source: Meder 2011, based on EEA 2003.

Apart from the large EEPCo hydropower schemes, particularly small scale hydropower potential has hardly been exploited so far. In the period between 1950 and 1970, EEPCo

[4] Given that average pressure heads for potential pico and micro hydropower sites are 45 m, using a 60% system efficiency and a specific minimum flow of 2 l/s/km^2.

installed several MHP schemes with a total capacity of 1.5 MW. All of them are not operational anymore: once the areas were connected to ICS, the MHP plants were shut down. Nonetheless, some of the plants are still in good condition and it would be technically feasible to rehabilitate those (BÖLLI, FEIBEL 2008). The same holds true for the Yaye MHP. The 170 kW off-grid plant was commissioned in 2002 by the Irish Development Aid and the Sidama Development Program but already suffered from low river flow during the 2002/2003 dry season. After only having operated for two years, EEPCo connected Yaye to its ICS and the MHP plant was shut down completely (GROSS, BÖLLI 2009) (see footnote 11). Furthermore, several PHP schemes as well as 32 cross flow turbines exist, which power flour mills with outputs ranging between 5 and 22 kW. Latter were commissioned by Ethiopian Evangelical Church Mekane Yesus (EECMY). Nonetheless 35-40% of those plants are not operational anymore due to a lack of water during dry season and management as well as technical problems (IED 2006). EECMY and REF are planning the installation of further MHP plants such as a 55 kW scheme on the Bege River and a 5.5 kW scheme in Sire (BÖLLI, FEIBEL 2008). In 1994 the Ethiopian NGO Ethiopian Rural Self-Help Association (ERSHA) implemented another hydro-powered grain mill near Ambo, which is said to be still operational (IED 2006). Additionally, the current GTP (2010 – 2015) includes the installation of 65 MHP plants (ETHIO RESOURCE GROUP 2011). No further details regarding capacity and location of the latter are available at the time.
GIZ ECO Ethiopia is currently implementing four pilot MHP sites in the Sidama Zone/SNNPR with a capacity of 7 kW, 30 KW, 33 kW and 55 kW respectively. The sites as well as environmental and socio-economic impacts of MHP schemes will be elaborated on in chapter 3.

2.2.2 Solar energy

Ethiopia receives a solar irradiation of 5000 – 7000 Wh/m^2 according to region and season and thus has great potential for the use of solar energy (BÖLLI, FEIBEL 2008) (see fig. 8). Although the growth rate is increasing (from <5% since the early 1990s to 15 – 20% in the last few years), primarily driven by the telecommunication sector which contributes 70% to the installed capacity, the solar PV market is still at its early stage. With an installed capacity of approximately 5 MW and an estimated PV market potential of 52 MW, with a majority in the solar home system (SHS) market and a further expansion of the telecommunication sector, not even 10% of the potential is exploited. Costs for SHS are relatively high and unlike costs for MHP systems, cannot be reduced by connecting more customers. In the near future, larger and particularly grid-connected solar energy systems will thus compete with small-scale hydropower systems (GTZ 2009; BÖLLI, FEIBEL 2008). Next to the PV SHSs, there is also a market for solar water heating (SWH) systems that use solar irradiation to heat up water, which can significantly reduce fuel wood and electricity consumption. Unlike PV systems, SWH systems have not been monitored in the past and thus accurate data is missing. Nevertheless it is estimated that 5,000 units are installed,

which is equivalent to an area of 10,000 m^2 (GTZ 2009; BÖLLI, FEIBEL 2008). The 2010 – 2015 GTP of the Ethiopian government furthermore includes the dissemination of 153,000 SHSs and 3 million solar lanterns (ETHIO RESOURCE GROUP 2011). The GIZ ECO Ethiopia also works in the solar power sector (see chapter 3).

Solar Irradiation in Ethiopia (in kWh/m2/day)

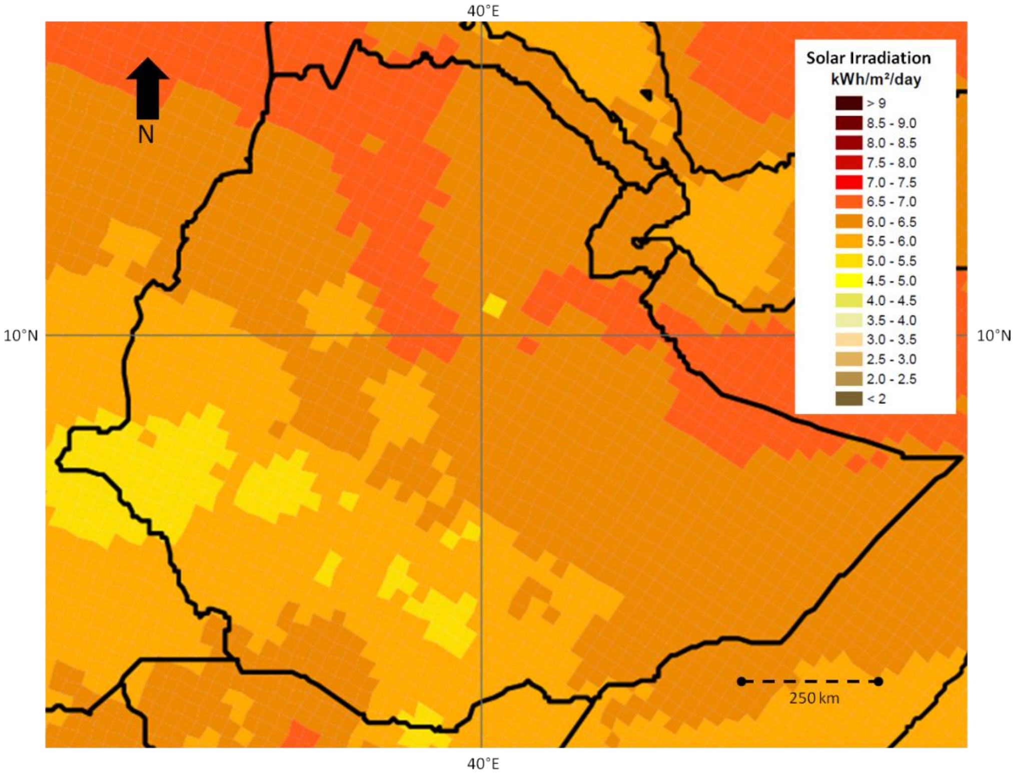

Fig. 8: Solar irradiation in Ethiopia (in kWh/m2/day). Source: Meder 2011, based on SWERA et al. 2005.

2.2.3 Biomass

Biomass resources include wood, agro-industrial residue, municipal waste and bio fuels. Wood and agricultural as well as livestock residue are used beyond sustainable yield with negative environmental impacts. There is however an energy production potential from agro-processing industries (processing sugar cone bagasse, cotton stalk, coffee hull and oil seed shells) (ETHIO RESOURCE GROUP 2009). Up to date, no grid-connected biomass power plants exist. Several sugar factories have however been using sugar cane bagasse for station supply since the 1950s. A total of 30 MW of capacity surplus could be fed in the grid by sugar factories (LOY 2007). Municipal waste and bio fuels on the other hand are barely used as energy resources. No estimation of municipal waste power production

potential is available at the time, power production potential of landfill gas[5] is estimated to be 24 MW (ETHIO RESOURCE GROUP 2009). The current GTP plans to disseminate 25,000 domestic biogas plants, 10,000 vegetable oil stoves and 9.4 million improved stoves by 2015 (ETHIO RESOURCE GROUP 2011). The GIZ ECO Ethiopia also works in the biomass sector, promoting improved stoves (see chapter 3).

2.2.4 Wind energy

Ethiopia has good wind resources with velocities ranging from 7 to 9 m/s (WALELU 2006) (see fig. 9). Its wind energy potential is estimated to be 10,000 MW (LOY 2007).

Annual Mean Wind in Ethiopia
(Power Density in W/m2 and Velocity in m/s)

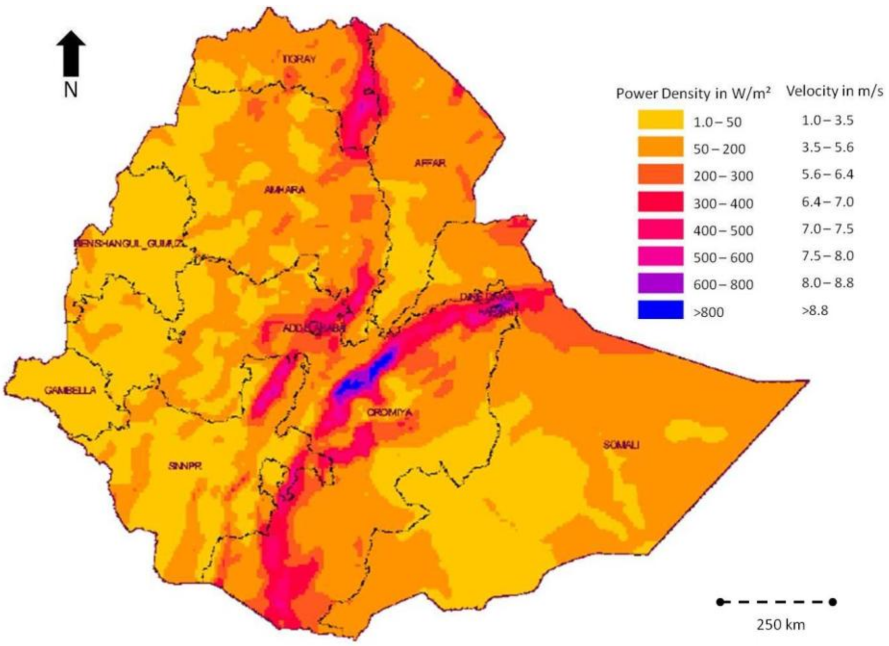

Fig. 9: Annual Mean Wind in Ethiopia (Power Density in W/m2 and Velocity in m/s). Source: Meder 2011, based on ETHIO RESOURCE GROUP 2009.

Up till now, no commercial wind energy power plants exist, nevertheless EEPCo is planning to develop seven wind sites that are in close proximity to the ICS by 2015, ranging between 50 and 300 MW. In sum, the installed wind power capacity would be approximately 720 MW (BEYENE, HERZIG 2011). Wind energy is considered a promising complementation to hydropower, since the two resources unfold their potential anti-

[5] Gas that is generated by decomposition of organic material at landfill sites (ETHIO RESOURCE GROUP 2009).

cyclic: in rainy seasons the hydropower potential is high whereas low winds prevail. Vice versa hydropower potential is low in the dry season whereas the wind potential is high (see fig. 10). Compared to large hydropower plants, wind energy plants are considered to show minor negative environmental impacts (WALELU 2006).

Wind Production Complementary to Hydropower

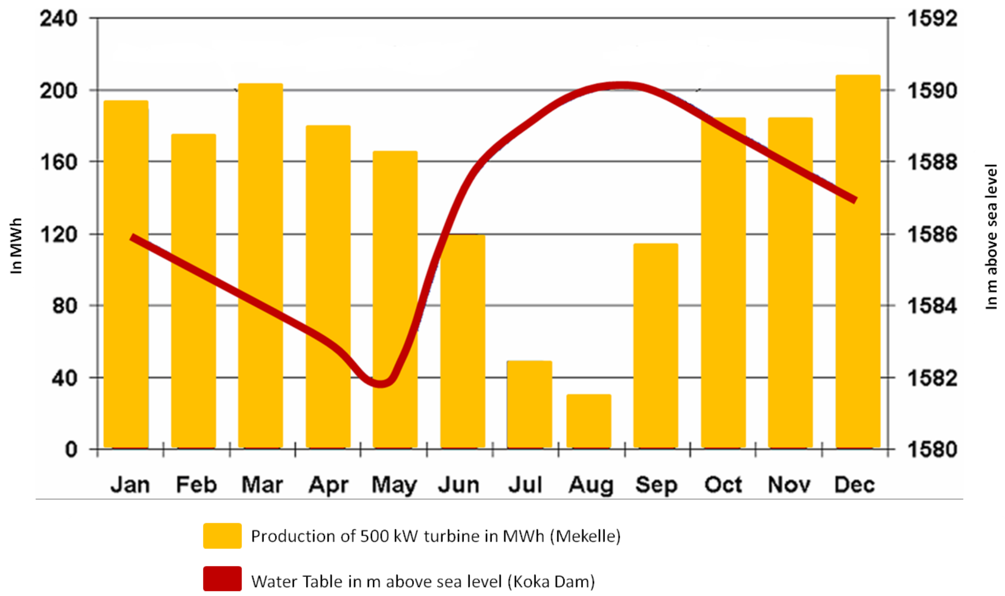

Fig. 10: Wind production complementary to hydropower, example comparing wind production in Mekelle (in MWh) and hydropower resource at Koka Dam (in m above sea level). Source: Meder 2011, based on JARGSTORF 2004.

2.2.5 Geothermal energy

Ethiopia's geothermal resources are estimated to be 5 GW of which 700 MW are suitable for electric power generation (ETHIO RESOURCE GROUP 2009; LOY 2007). Geothermal resources are primarily located in the Rift Valley area, where temperatures of 50 – 300°C prevail in a depth of 1,300 – 2,500 m. Only one 7.3 MW geothermal power plant has been commissioned so far, which started operating in 1998/1999 but was shut down due to lacking technical maintenance in 2002 (EEPCo 2005; ETHIO RESOURCE GROUP 2009; LOY 2007). Operation was taken up again, but only at a much reduced generation rate. Exploration of geothermal resources is still ongoing.

3. GIZ Energy Coordination Office (ECO) Ethiopia

For the past 10 years, GIZ (GTZ respectively[6]) has worked with the Ethiopian government and other partners to promote and introduce sustainable energy services as well as energy-saving methods and products in Ethiopia (GTZ 2010a). GIZ's Energy Coordination Office (ECO) is supporting sustainable energy services in Ethiopia through the Dutch-German Energizing Development (EnDev) program[7], which includes three branches:

(1) Policy, private sector development and services

The department advises the Ethiopian Government on policies, strategies, laws and programs and helps to increase private sector involvement in the renewable energy sector. Furthermore info-sharing and awareness-raising among partners, stakeholders and general public as well as capacity building of partners is promoted. Additionally the department supports partners in identifying appropriate modern energy interventions and funding opportunities (GROSS, BÖLLI 2009).

(2) Electrification

ECO's electrification department promotes rural electrification by building up local capacities and international linkages for the provision of small-scale solar and micro hydropower schemes.

(3) Bio-energy

The bio-energy department promotes improved energy-efficient cooking technologies, such as Mirt baking stoves[8], Tikikil household stoves, and institutional rocket stoves[9].

GIZ ECO is funded by the Dutch Directorate-General for International Cooperation (DGIS) and the German Ministry for Economic Cooperation and Development (BMZ) (GIZ 2011d).

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[6] As of January 1, 2011 the former GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit GmbH) was merged together with DED (Deutscher Entwicklungsdienst) and InWent (Internationale Weiterbildung und Entwicklung). This newly formed and federally owned enterprise is called GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) and supports the German Government in the field of international cooperation for sustainable development (GIZ 2011c).

[7] EnDev works in developing countries throughout Africa, Asia and South America and recognizes that access to energy is critical for sustainable development, poverty reduction and thus to achieving the MDGs. The program, which was launched in 2005, aims to provide 5 million people in developing countries sustainable access to modern energy services by 2015 (GTZ 2010b).

[8] Used for baking injera, reduces fuel consumption by 50% (GTZ 2010c).

[9] Tikikil household stove and institutional rocket stove are used for cooking, reduce fuel consumption by 40 to 70% (GTZ 2010c).

It cooperates with Ethiopian as well as international partners such as the Ethiopian Ministry of Mines and Energy (and associated organizations such as EEPCo, EAEDPC and EEA), the Ethiopian Ministry of Agriculture and Rural Development, the Ethiopian Environmental Protection Agency (EPA), the World Bank, several UN organizations as well as other governmental and non-governmental organizations, universities and the private sector (GTZ 2010a).

As mentioned above, GIZ ECO's electrification department promotes rural off-grid electrification by building MHP sites. Four pilot sites are currently implemented in the villages Gobecho, Hagara Sodicha and Ererte in the Sidama zone/SNNPR/Ethiopia (see fig. 11).

Location of GIZ ECO MHP pilot sites

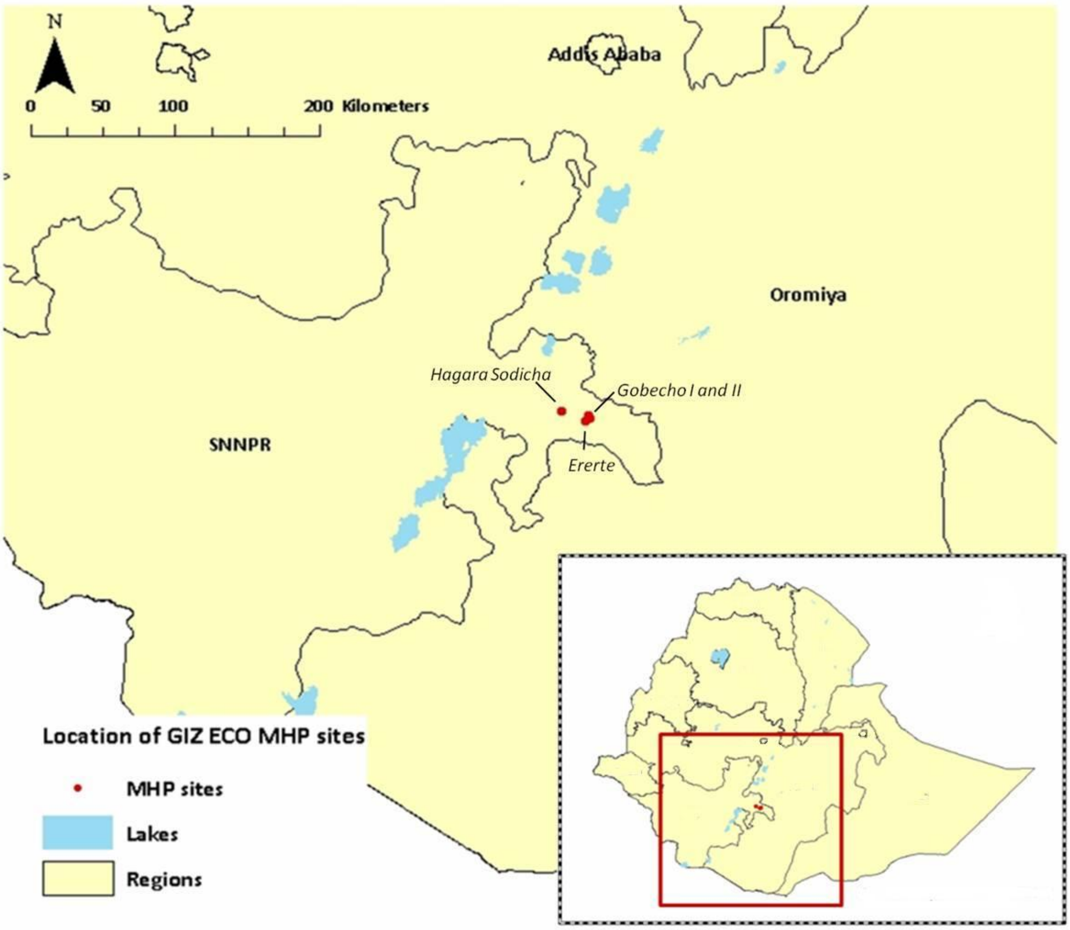

Fig. 11: Location of GIZ ECO MHP sites. Source: Meder 2011, based on MAPLIBRARY 2011.

3.1 Objectives of GIZ ECO MHP development: impacts

The objectives of the GIZ ECO hydro component are to improve the conditions in the Ethiopian energy sector, to make lower-income households, social facilities, and small and medium enterprises benefit from greater access to modern energy technologies and/or services and thus to contribute to reaching the UN Millennium Development Goals (MDGs)[10].

Compared to large hydropower projects, small-scale hydropower schemes have relatively low negative environmental and socio-economic impacts. As recent evaluation studies on MHP projects and the along going electricity supply suggest, particularly socio-economic impacts of the plants are to be considered positive. Just like other off-grid renewable energy applications, MHP schemes have a variety of direct and indirect positive impacts, which are often interrelated. Electricity supplied by MHP enhances income generation (agro-processing and small service business such as mills and shops) and enables inhabitants to make savings on expenses such as kerosene, gasoline, candles and batteries. Income increase and savings as well as the possibility to use refrigeration improve the diet and thus decrease malnutrition and hunger (GONZÁLEZ, ARISTIZÁBAL, MONTERDE 2009; GIZ 2011b). Moreover, women's and children's work load decreases, since they spend less time on energy related household tasks such as the collection of fire wood and water gathering. As mentioned above, that does not only reduce physical impairments resulting from the heavy loads, but also reduces the risk of harassment and sexual assault and thus HIV/AIDS risk. The communities' safety in general improves due to street lighting at night. Furthermore women and children have more productive time which can be used for studying and thus education is improved. Electricity supply allows lighting at night and gives inhabitants the chance to study during evening hours. Latter also improves the communities' social life, since community gatherings at night are possible and it benefits from electrical devices such as TV and radio. Furthermore telecommunication is enhanced. People get more aware of the outside world which gives them more knowledge (KORKEAKOSKI 2009). The electricity provided by the MHP has a positive impact on the communities' health situation, since it decreases indoor air pollution and the risk of fire. Moreover it allows the use of refrigerators for medicine (keyword: vaccination) and groundwater pumps. Latter reduce water borne diseases due to contaminated surface water. Due to the enhanced technical equipment, more doctors and teachers are attracted to the mostly remote areas, which further improve health and education services (GIZ 2011b; GONZÁLEZ, ARISTIZÁBAL, MONTERDE 2009). In environmental terms, the MHP project

[10] The UN Millennium Goals are 8 international development goals that all UN member states agreed to achieve by 2015. The MDGs were established subsequent to the UN Millennium Summit in 2000 (UN 2011).

raises the awareness of proper watershed management and reforestation to secure the sustainable use of water resources. Moreover the plants contribute to protect the environment and combat climate change through reduced use of kerosene/gasoline and small batteries (GIZ 2011b). Generally it should be noted that impacts not only depend on the MHP itself, but also on what training and campaigns go along with its implementation and in what way the communities tap the full potential of the electricity supply. An overview on how MHP plants can contribute to achieve the MDGs can be found in table 2.

Tab. 2: Contribution of MHP to achieve Millennium Development Goals (MDGs).
Source: GIZ 2011b; GONZÁLEZ, ARISTIZÁBAL, MONTERDE 2009.

<table>
<tr><th colspan="2">Micro Hydropower (MHP) and Millennium Development Goals (MDGs)</th></tr>
<tr><td>MDG 1:
End Poverty and Hunger</td><td>MHP generated electricity can be useful for agro-processing and small service business (mills, shops…), which generate jobs and income. Expenditures for candles and kerosene/gasoline decrease. Food processing and refrigeration allow an improvement of diet, contributing to reduction of hunger and malnutrition.</td></tr>
<tr><td>MDG 2:
Universal Education</td><td>Due to the electricity supplied by the MHP, students can study during evening hours and spend less time in energy related activities such as collection of firewood. Power supply in schools attracts teachers to rural areas and allows use of multimedia tools.</td></tr>
<tr><td>MDG 3:
Gender Equality</td><td>MHP generated electricity can reduce the time females spend on household tasks such as collection of fuel wood. Therefore, they have more time to study and become literate. Other jobs traditionally reserved to women such as shopkeeper or craftworks may improve with the access to electricity. Public lighting improves public safety in rural communities, which is very important for women.</td></tr>
<tr><td>MDG 4:
Child Health</td><td rowspan="2">MHP decreases indoor air pollution of kerosene/gasoline smoke and candles and improves safety around the house. In addition to the better diet and more hygienic cooking conditions, mothers and children can benefit from improved medical service. The electricity supplied by the MHP enables refrigeration, adequate lighting, telecommunication and use of medical technology, which in turn, permit vaccination, sterilization and an improvement in time and quality of the medical service. Electricity supply also allows the use of ground water pumps, thus water borne diseases due to contaminated surface water can be decreased.</td></tr>
<tr><td>MDG 5:
Maternal Health</td></tr>
<tr><td>MDG 6:
Combat HIV/AIDS</td><td>MHP contributes to the general improvement of medical services (keywords: access and refrigeration) and awareness of diseases rises due to campaigns on radio and TV.</td></tr>
</table>

MDG 7: Environmental Sustainability	MHP contributes to the environmental sustainability and combats climate change through reduced use of kerosene/gasoline and small batteries. Additionally there is an increased awareness of the importance of a proper watershed management and reforestation to secure long term water resources.
MDG 8: Global Partnership	MHP improves the access to information and telecommunication (via TV, radio, mobile phones). These are crucial inputs for raising awareness and allowing the creation of networks and interest groups.

Since no large reservoirs are required, no resettlement programs and the along going negative impacts for the population occur. Nonetheless some scientist argue that particularly the environmental impacts of small-scale hydropower, when widely used, would be no less serious per kW generated than those from large scale hydropower plants (ABBASI, ABASSI 2011). The impacts of hydropower schemes depend on the way they are designed (ESHA 2009). Since MHP and PHP schemes do not require a reservoir and divert only part of the stream water away from a portion of the river to power the turbine, they only have little impact on the flora and fauna of the vicinity. However they tend to create small, shallow pools which can cause problems such as sedimentation as well as eutrophication and can thus affect water quality and lead to greenhouse gas emission. Particularly a decrease of water quality can cause water borne diseases and thus affect the health situation of the population. Moreover aquatic species can be affected negatively in terms of migration and change of habitat condition (ESHA 2009). Due to the MHP and the along going electricity supply, a population growth close to the powerhouse is likely to occur. Accordingly the pressure on natural resources and the risk of erosion in areas close to the powerhouse is increased. Consequences might be that a sustainable use of the MHP cannot be provided. Further environmental impacts might be deforestation due to the construction of access roads and grid connection power lines (THORADENIYA, RANASINGHE, WIJESEKERA 2007).

It should be noted, that some features might be considered positive in socio-economic terms but negative in environmental terms and vice versa. Taking the construction of access roads as an example, it has negative impacts on the environment since increased deforestation occurs but positive socio-economic effects in terms of increased access to the market and (in some areas) increased income from tourism. When constructing an MHP scheme, it is thus of great importance to be aware of complex interdependencies between positive as well as negative environmental and socio-economic impacts and benefits which can vary between population groups in terms of income and location of their households. It should be deliberated on whether the benefit of the MHP implementation exceeds possibly occurring negative impacts, taking into account

environmental as well as socio-economic features. The schemes' impacts on the health situation can be taken as an example: the plants' environmental impacts such as decreased water quality might affect population's health, nonetheless the electricity supply might also improve the overall health situation due to refrigeration, improved access to medication as well as increased income to purchase medicine. Generally, negative impacts should be kept to a minimum by incorporating and implementing respective mitigation techniques already in the planning and construction phase of the MHP project.

3.2 GIZ ECO MHP pilot sites

As mentioned above, four GIZ ECO pilot sites are currently implemented in the villages Gobecho, Hagara Sodicha and Ererte in the Sidama zone/SNNPR/Ethiopia[11] (see fig. 11). Each site will be elaborated on in the following. The data provided is based on information from GIZ ECO staff members:

3.2.1 Gobecho I

The MHP plant Gobecho I has a capacity of 7 kW. It has been commissioned in February 2011 and is estimated to have the capacity to supply a total of 700 persons with electricity (given that no public facilities such as schools and health centers are connected). As of May 2011, the plant supplied energy for 16 households (which equals 160 connected persons, given that the average household size in the area is 10 persons), 9 coffee places, 5 shops, a cinema, a health center, a school as well as a church.

3.2.2 Gobecho II

The MHP plant Gobecho II has a capacity of 30 kW and will be commissioned in November 2011. Current estimations show that approximately 200 households will be connected to the plant. The maximum number of households that could be supplied is estimated to be 700 (given, as mentioned above, that no public facilities such as schools and health centers are connected).

[11] Aside from the implementation of the four MHP pilot sites, further activities of the GIZ ECO hydro component is to rehabilitate the 170 kW Yaye MHP plant, which was completely shut down when Yaye town was connected to EEPCo's ICS after only one year of operation in 2003 (see chapter 2.2.1.2). It is planned to feed the generated power into the national grid, once the scheme is operational again. Nonetheless the actual implementation of the project is ambiguous since, as of today financial and political matters remain uncertain. Furthermore GIZ ECO hydro supports the upgrading of a watermill in Jimma and 10 kW MHP plant in Kersa. In order to further enhance local capacities, GIZ ECO furthermore works on the establishment of centers of excellence in cooperation with different Ethiopian universities.

3.2.3 Hagara Sodicha

The MHP plant Hagara Sodicha has a capacity of 55 kW and will be commissioned in November 2011. The plant is estimated to supply 300 to 400 households with electricity (maximum number of connectable households is 1000, considering no public facilities are connected).

3.2.4 Ererte

The MHP plant Ererte has a capacity of 33 kW and has been commissioned in May 2011. Similar to the Gobecho II scheme, a total of approximately 200 households will be connected to the plant. The maximum number of potentially connectable households is 700.

Since the projects have only been launched recently and are still under construction respectively, actual connection rates have yet to be determined. The uptake of connection rates of the first operational plant Gobecho I is slower than expected. According to GIZ ECO staff, reasons are most likely of financial nature. Since each household needs to pay a connection fee for the initial connection, people might not be able to afford the latter and/or are expecting financial support through the project. Furthermore it is assumed that, due to the short time of operation, people are not yet convinced of the long term benefits they would gain from a connection to the MHP plant. In general, it is expected that more people will move close to the powerhouse once the plant runs consistently and people learn more about its benefits.

3.3 GIZ ECO hydropower manuals

In the scope of the four pilot projects, best practice approaches are being developed in order to be able to promote the technology nationwide in the future. As of today, the GIZ ECO hydro component has developed several best practice manuals, all of them addressing various topics related to MHP project implementation. GIZ ECO recognized that environmental sustainability is crucial for the sustainable use of the MHP plants and thus a manual on environment assessment (EA) and watershed action planning (WAP) was prepared in order to include environmental issues in each future MHP implementation. A list of the existing manuals can be found in table 3. The EA and WAP manual developed in the scope of this study is one of these best practice manuals.

Tab. 3: List of GIZ ECO hydropower manuals. Source: GIZ ECO staff information.

List of GIZ ECO hydropower manuals	
1.	Results of the Value Chain Analysis for the SNNPR region and a framework for conducting similar analysis in other regions
2.	Analysis of business potentials for private owned MHP, considering both scenarios, one with Feed-in tariff effective and one without
3.	Management models for private and community owned MH
4.	Guidelines to support rural communities to prepare applications for MHP projects
5.	Guidelines to support the Management and Committees of Electric Energy Cooperatives (on Organization and Planning, Finance Management, Controlling, Communication) **5.1** Legal framework for Cooperatives **5.2** Planning guide for Cooperatives **5.3** Communication Management CCA **5.4** Operations management for Coops **5.5** Service Management for Coops **5.6** Financial Management for Coops
6.	Standard manuals for the training of the Management and Committees of Electric Energy Cooperatives (in planning, organization, finances, controlling and communication) **6.1** Training manuals for Planning and organization in Cooperatives **6.2** Training manuals for Financial management in Cooperatives **6.3** Training Manuals for Service management in Cooperatives **6.4** Training manuals on cooperatives communication through community conversation for action **6.5** Training manuals for operation and maintenance
7.	Proposals to rural communities in regard to possibilities of "productive use" of the supplied energy and advice on related BDS support needed by local businesses.
8.	Final and terminal report of the assignment
9.	Environment Assessment (EA) and Watershed Action Planning (WAP)

4. Introduction to the Research Area: a general overview

This chapter provides environmental as well as socio-economic information on the larger geographical area the research sites are located in. Starting with a general introduction to Ethiopia, the focus will mainly be on the Eastern Ethiopian Highlands and, more precisely, the woredas[12] Aleta Wendo, Arbegona and Hula[13] in the Sidama zone southeast of Awassa (see fig. 2, 12 and 13).

Location of the wider research area

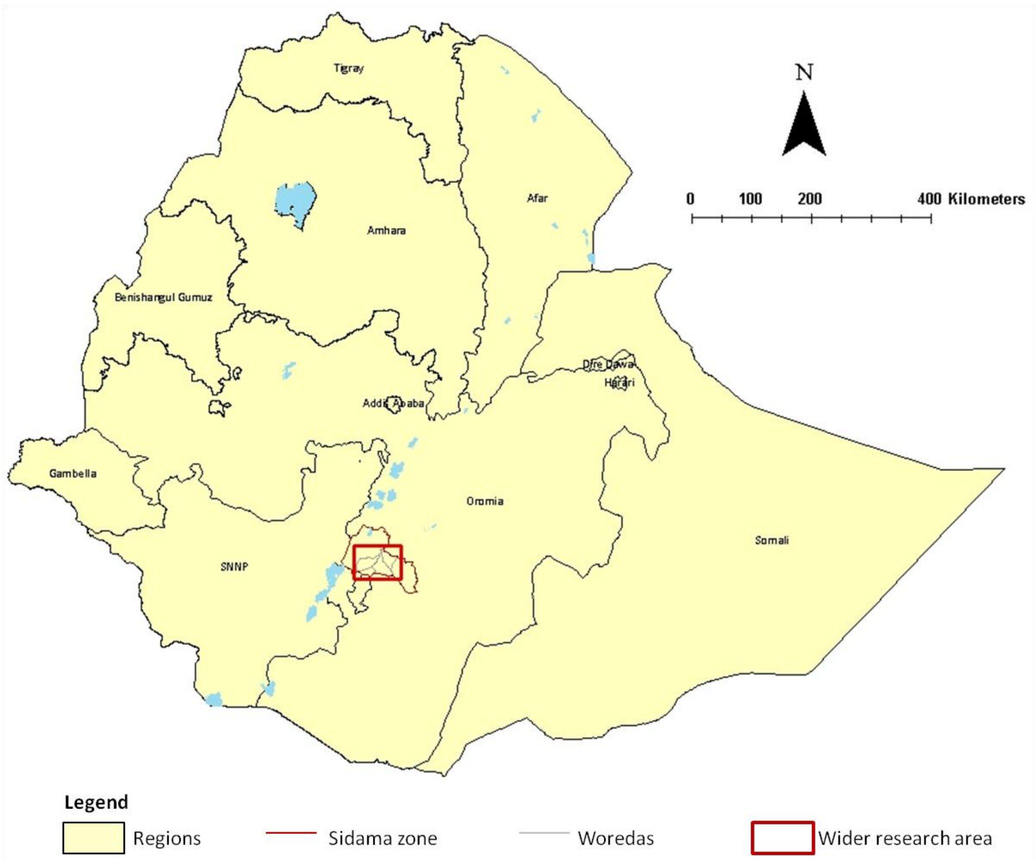

Fig. 12: Location of the wider research area. Source: Meder 2011, derived from MAPLIBRARY 2011.

[12] Equivalent to "district". Administratively, Ethiopia is divided into regions, zones, woredas and kebeles of which regions are the largest and kebeles are the smallest units (HUMAN RIGHTS WATCH 2010).

[13] Due to a recent change of administrative boundaries in the Sidama zone, the powerhouses of Gobecho I and II as well as part of the catchment is located in the newly created Bona woreda, which was composed of 15 kebeles from Hula and 13 kebeles from Arbegona woreda (UN 2008). However, in the scope of this study, the old administrative division will be the basis of analysis, since the database as well as map material for the newly established woreda is insufficient.

Particularly socio-economic data presented in this chapter will be based on the entire Sidama zone and, if available, the woredas Aleta Wendo, Arbegona and Hula, since detailed and sufficient data is primarily available for the political units. Since the research sites themselves, namely the catchment areas of the MHP plants Gobecho I (and II) as well as Hagara Sodicha, will be elaborated on regarding environmental condition, land use and land cover in chapter 7, the following chapter only provides a basic overview on the environmental as well as socio-economic situation.

4.1 Ethiopia

Ethiopia is a land-locked country located in East Africa and extends from about 3°24' to 14°53' N latitude and from 33°00' to 48°00' E longitude. The country's north-south extension is approximately 1270 km whereas the west–east axis is approximately 1650 km long. The area is 1,104,300 km^2. Ethiopia's neighboring countries are (clockwise from the north) Eritrea, Djibouti, Somalia, Kenya and Sudan. Altitudes range from 125 m below sea level (Danakil Depression) and 4533 m above sea level (Ras Dejen), thus, the country's relief intensity is 4658 m. Although the peaks are not as high as in Kenya, Tanzania and Uganda, Ethiopia has more ground above 2000 m than any other African country (FRIIS, DEMISSEW, BREUGEL 2010; CIA 2011). In general, the topography is dominated by the central highlands, surrounded, except to the north, by lowlands. The highlands are divided by the Great Rift Valley, cross-cutting the country from the southeast to the northeast, ending in the triangular Afar lowlands. Ethiopia can be divided into 10 major river basins (see fig. 17). Due to the predominant westward slope of the Western highlands, many large river systems, such as the Abay (Blue Nile), the Tekeze and the Baro system are tributaries of the Nile system. The annual runoff amounts to 122.19 billion m^3 (FRIIS, DEMISSEW, BREUGEL 2010; INSTITUTE OF BIODIVERSITY CONSERVATION 2005).

Ethiopia's geology is dominated by a up to 1,000 m thick basaltic shield (trap), which resulted from a massive uplift of the highlands and an along going outpour of lava in the Tertiary. Thus, the geological structure of the latter are dominated by Tertiary extrusive and intrusive rocks whereas the northern part, southeastern part, Blue Nile gorge and Northeastern part are dominated by Precambrian, Palaeozoic and Mesozoic rocks as well as Quaternary extrusive, intrusive and eolian formations respectively. The composition of soil types is highly complex and primarily depends on the topography (FRIIS, DEMISSEW, BREUGEL 2010).

In general, the climate of Ethiopia is characterized by a moderate tropical climate in the highlands and hot and mostly arid climate in the lowlands. The annual precipitation in Ethiopia ranges from 800 to 2200mm in the highlands (above 1500 m above sea level) and varies from less than 200 to 800mm in the lowlands (beneath 1500 m above sea level) (REYNOLDS 2003a). Due to the complex climatic and topographic situation, three major

rainfall regimes can be differentiated throughout Ethiopia, which are primarily influenced by two alternating wind systems. The monthly average temperature, mainly a function of altitude, shows little seasonal variation (approx. 2°C variation in southern Ethiopia, and approx. 6°C in northern Ethiopia), whereas the daily variations may be considerable (daily temperature amplitude in Addis Ababa may be as much as 18°C) (FRIIS, DEMISSEW, BREUGEL 2010).

Vegetation types are being considered as ecosystems in Ethiopia and are classified as Afroalpine and Sub-Afroalpine (> 3200 m above sea level, characterized by Lobelia (*Lobelia rhynchopetalum*) and evergreen shrubs), Dry Evergreen Montane Forest and Grassland Complex (1900 – 3300 m above sea level, characterized by a mix of extensive grasslands rich in legumes, shrubs and trees and closed forests with canopies of several strata), Moist Evergreen Montane Forest (characterized by one or more closed strata of evergreen trees, divided into a) Afro-montane Rainforest at an altitude between 1500 and 2600 m above sea level and b) Transitional Rainforest, ranging between 500 and 1500 m above sea level), *Acacia-Commiphora* Woodland (900 – 1900 m above sea level, characterized by drought resistant trees and shrubs), *Combretum-Terminalia* Woodland (500 – 1900 m above sea level, characterized by small to moderate-sized trees), Lowland Semi-evergreen Forest (450 – 650 m above sea level, characterized by semi-deciduous forest), Desert and Semi-desert Scrubland (<500 m above sea level, characterized by highly drought tolerant species) and Inland Waters (including running (lotic) and standing (lentic) water bodies such as rivers, lakes, wetlands, swamps and reservoirs, prevailing flora highly depends on altitude and geographic location) (INSTITUTE OF BIODIVERSITY CONSERVATION 2005).

Due to Ethiopia's location near the equator, elevation has a strong influence on temperature and rainfall and thus on the agricultural potential. In order to describe relatively homogenous agricultural land use options and to characterize different environments, Ethiopia is commonly classified in five traditional agroecological divisions. **Bereha** refers to hot lowlands of less than 500 m above sea level. In the arid east, Bereha crop production is very limited while in the humid west, mixed root crops and maize are grown. **Kolla** refers to lowlands between 500 and 1,500 m above sea level. Predominant crops are sorghum, finger millet, sesame, cowpeas, and groundnuts. **Woina Dega** refers to highlands between 1,500 and 2,300 m above sea level. Prevailing crops are wheat, teff, barley, maize, sorghum, and chickpeas. **Dega** refers to highlands between 2,300 and 3,200 m above sea level. Predominant crops are barley, wheat, oilseeds, and pulses. **Wurch** refers to highlands between 3,200 and 3,700 m above sea level and barley is the principal crop. **Kur** refers to highland areas above 3,700 m above sea level, which are primarily used for grazing (HURNI 1998; IFPRI, CENTRAL STATISTICS AGENCY 2006). Furthermore, the Ethiopian Ministry of Agriculture and Rural Development developed a more detailed

system of agroecological zoning in which 18 major zones are distinguished based on temperature and moisture regimes. Each of these zones has characteristic crops. This more detailed classification thus highlights fundamentally different production environments across the (arid eastern and humid western) lowlands and the highlands (which are moister in the west than in the north), while taking temperature and rainfall patterns into account (IFPRI, CENTRAL STATISTICS AGENCY 2006).

Ethiopia's economy is based on agriculture, which contributes 42.9% to the GDP and accounts for 85% of employment. The industrial and service sectors account for 13.7% and 43.4% respectively of the GDP (CIA 2011). Due to its dependency on agriculture, the economy is frequently prone to drought.

4.2 Eastern Highlands/Sidama zone

The research sites are located in the Eastern Ethiopian Highlands and, more precisely, in the woredas Aleta Wendo, Arbegona and Hula in the central Sidama zone/SNNPR, approx. 45 km (air line distance, driving distance is approx. 125 km) southeast of the zone's administrative center Awassa (see fig 2 and 13). The three woredas account for a total area of 1640 km^2.

Elevation and political boundaries of the wider research area

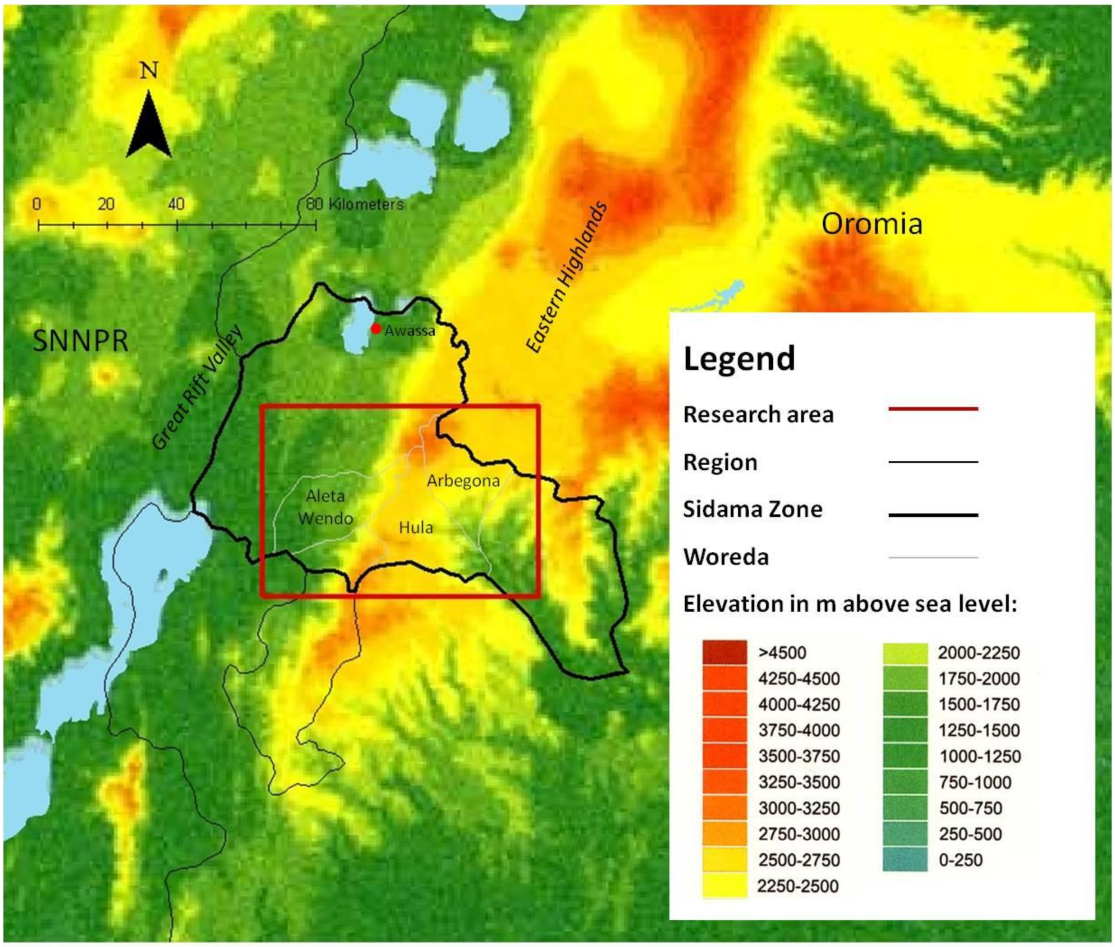

Fig. 13: Elevation and political boundaries of the wider research area. Source: Meder 2011, based on FRIIS, DEMISSEW, BREUGEL 2010 and MAPLIBRARY 2011.

4.2.1 Topography

The topography of the larger geographical area is characterized by the sharp west – east transition from the comparatively low altitude rift valley (approx. 1700 m above sea level) to its high altitude eastern margin – the Eastern Highlands (with elevations in this area up to 3338 m above sea level). In the southeast of the wider research area, the terrain drops

towards the southeastern lowlands (see fig. 13). The research sites themselves are located in the highland area, which is characterized by the alternation of undulating landscapes with deep valleys and steep slopes.

4.2.2 Geology

Located in the Eastern Highlands and thus on the eastern shoulder of the Great Rift Valley, the geology of the area is characterized by tertiary intrusive and extrusive rock and thus a trap series of lava deposit, which was (further) uplifted during the formation of the Rift Valley in the Tertiary.

Geology of the wider research area

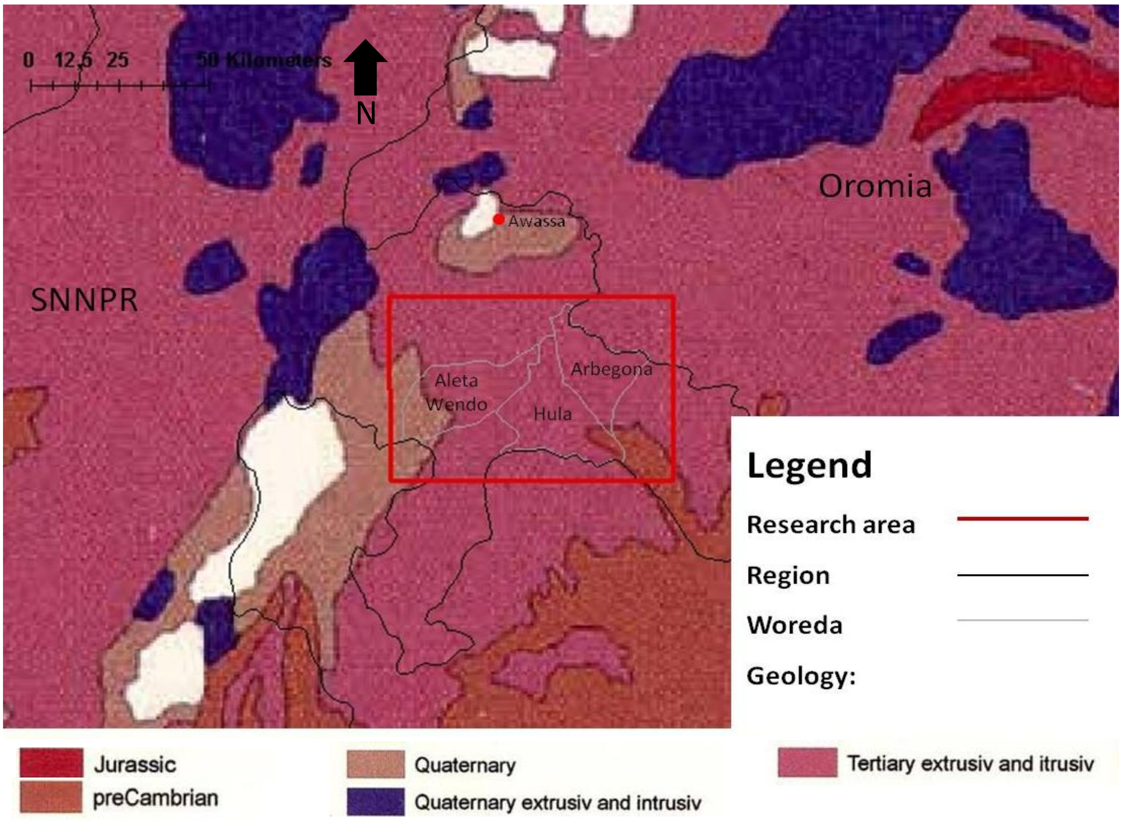

Fig. 14: Geology of the wider research area. Source: Meder 2011, based on FRIIS, DEMISSEW, BREUGEL 2010.

The prevailing volcanic rock includes rhyolites, trachytes, tuffs, ignimbrites, agglomerates and basalts (FRIIS, DEMISSEW, BREUGEL 2010). As shown on the map, Quaternary and Pre-Cambrian rock can be found on the areas margins in the southeast and in the Rift Valley to the west respectively (see fig. 14).

4.2.3 Climatic characteristics

The area is characterized by a three season climate with a summer rain maximum ("Kirmet"), short spring rains ("Belgh") and a dry period ("Bega") in fall and winter (BELTRANDO, CAMBERLIN 1993) (see fig. 16). The Kirmet rainy season features long and heavy rains from mid-June to mid-September, which correspond to the main "meher" growing season. The "Belgh" rainy season is characterized by short and moderate rains from February to May. The dry season "Bega" occurs between the two rainy seasons from October to January. This season is characterized by sunny days and cold nights and mornings and corresponds to the "Meher" harvest season (REYNOLDS 2003b). The area is furthermore characterized by a high variability in rainfall and thus deviation from the norm rainfall pattern may occur as exemplarily shown in fig 15.

Rainfall variability in the wider research area in mm (2001 – 2007)

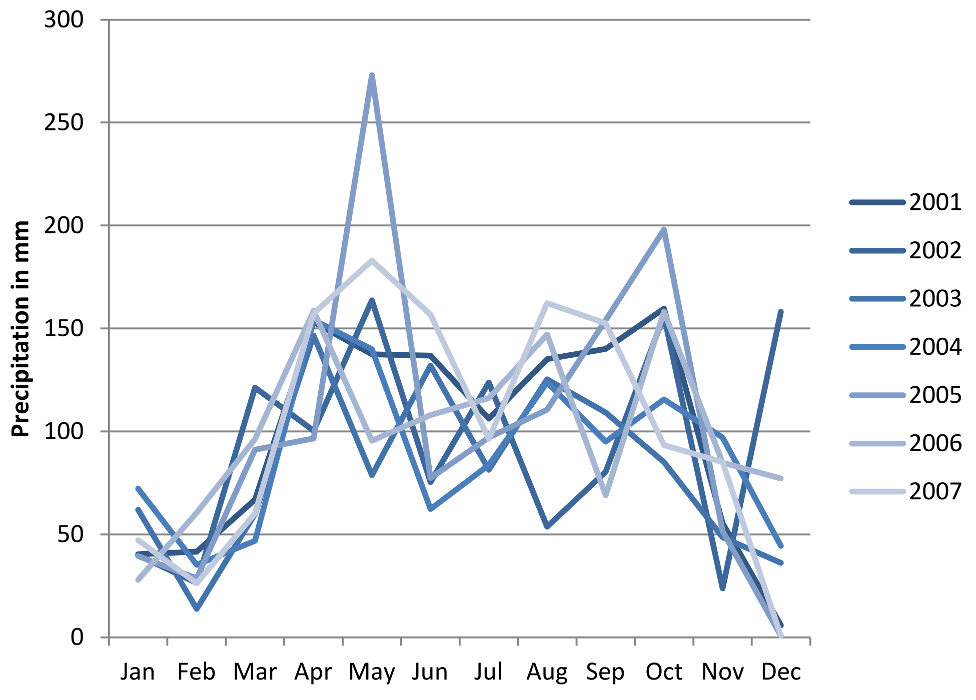

Fig. 15: Rainfall variability in the wider research area. Rainfall data was compiled at gauging stations in Arbegona, Hagare Selam and Bensadaye for the years 2001 - 2007. Source: Meder 2011, derived from GIZ ECO staff information 2011.

The annual precipitation amounts to 1200–1600 mm (IFPRI, CENTRAL STATISTICS AGENCY 2006). As mentioned above, the rainfall in Ethiopia mainly depends on the prevailing winds, which are in turn influenced by the movement of the intertropical convergence zone (ITCZ). While the ITCZ is located north of Ethiopia from May to October and prevailing winds are southwesterly and moisture-laden (monsoon), it is located south of

Ethiopia from November to April and prevailing winds are northeasterly, bringing only little moisture from the Red Sea (FRIIS, DEMISSEW, BREUGEL 2010).
The area's annual mean wind velocity is approx. 6 m/s (ETHIO RESOURCE GROUP 2009). Since no long term climate data was available for the wider research area, fig. 16 shows the climate diagram for Awassa, which is located northwest of the research area in the Rift Valley (see fig. 13).

Climate diagram Awassa/Sidama zone/SNNPR

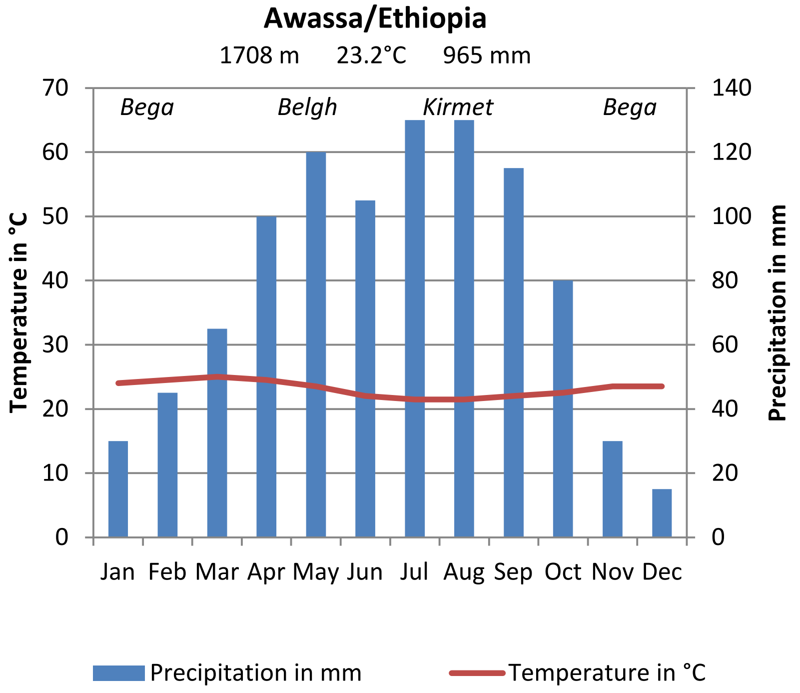

Fig. 16: Climate diagram Awassa/Ethiopia, survey period unknown. Source: Meder 2011, derived from WORLD CLIMATE 2011 and REYNOLDS 2003b.

Due to its lower elevation (approx. 1,700 m above sea level in contrast to approx. 2,500 m above sea level average elevation of the wider research area) it can be assumed that the actual rainfall amount in the wider research side is higher and the temperature is lower. Taking the data for Awassa (see fig. 16), with an annual average temperature of approx. 23.2°C and an elevation of approx. 1700 m above sea level as a basis and taking into account that the average annual temperature is a function of altitude, decreasing by approx. 0.6°C per 100 m increasing elevation, the average annual temperature for the Eastern Highland area southeast of Awassa (taking 2500m as the average elevation of the Woredas Aleta Wendo, Arbegona and Hula) is approx. 18.4°C (WORLD CLIMATE 2011; FRIIS, DEMISSEW, BREUGEL 2010). For more detailed rainfall data compare fig. 15, 26 and 55.

4.2.4 Soils

Major soil types in the highland area southeast of Awassa are Luvisols and Nitosols, which derive from the prevailing basaltic and other volcanic rock. The latter are deep and well-drained soils and have, just like Luvisols, relatively good agricultural potential (IFPRI, CENTRAL STATISTICS AGENCY 2006; FRIIS, DEMISSEW, BREUGEL 2010).

4.2.5 Hydrology

The area is crossed by the water divide between two of the 10 major Ethiopian river basins, the Rift Valley river basin and the Genale Dawa river basin, in a south–north direction (see fig. 17).

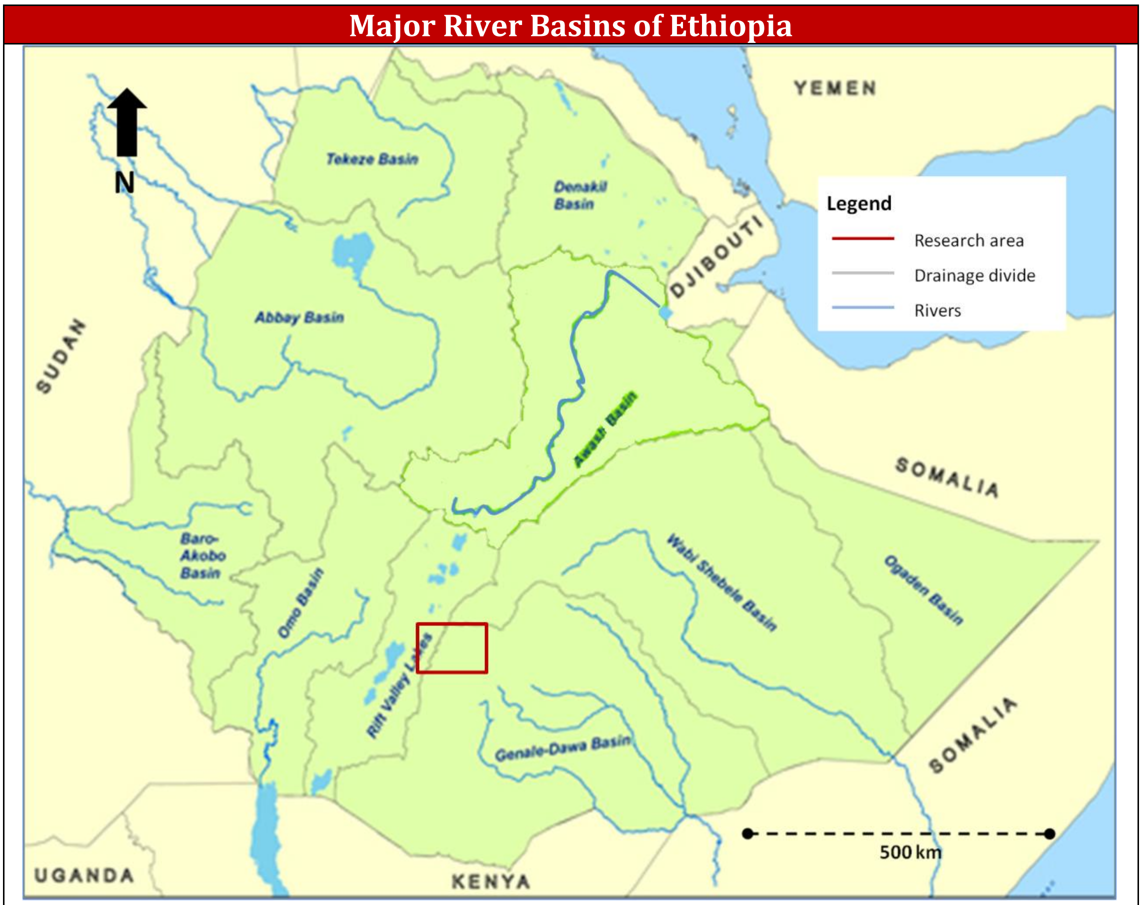

Fig. 17: Major river basins Ethiopia. Source: Meder 2011, based on AWMISET 2009.

The rivers located in the western parts of the area drain into the Rift Valley river basin and thus into the lakes located in the Great Rift Valley whereas the rivers located in the eastern parts drain into the Genale Dawa river basin and thus towards Somalia and then into the Indian Ocean (MINISTRY OF WATER AND ENERGY 2010).

4.2.6 Vegetation

In this part of the Eastern Highlands, the prevailing ecosystem is the Dry Evergreen Montane Forest and Grassland Complex (FRIIS, DEMISSEW, BREUGEL 2010; INSTITUTE OF BIODIVERSITY CONSERVATION 2005) (see fig 18).

Potential Natural Vegetation of the wider research area

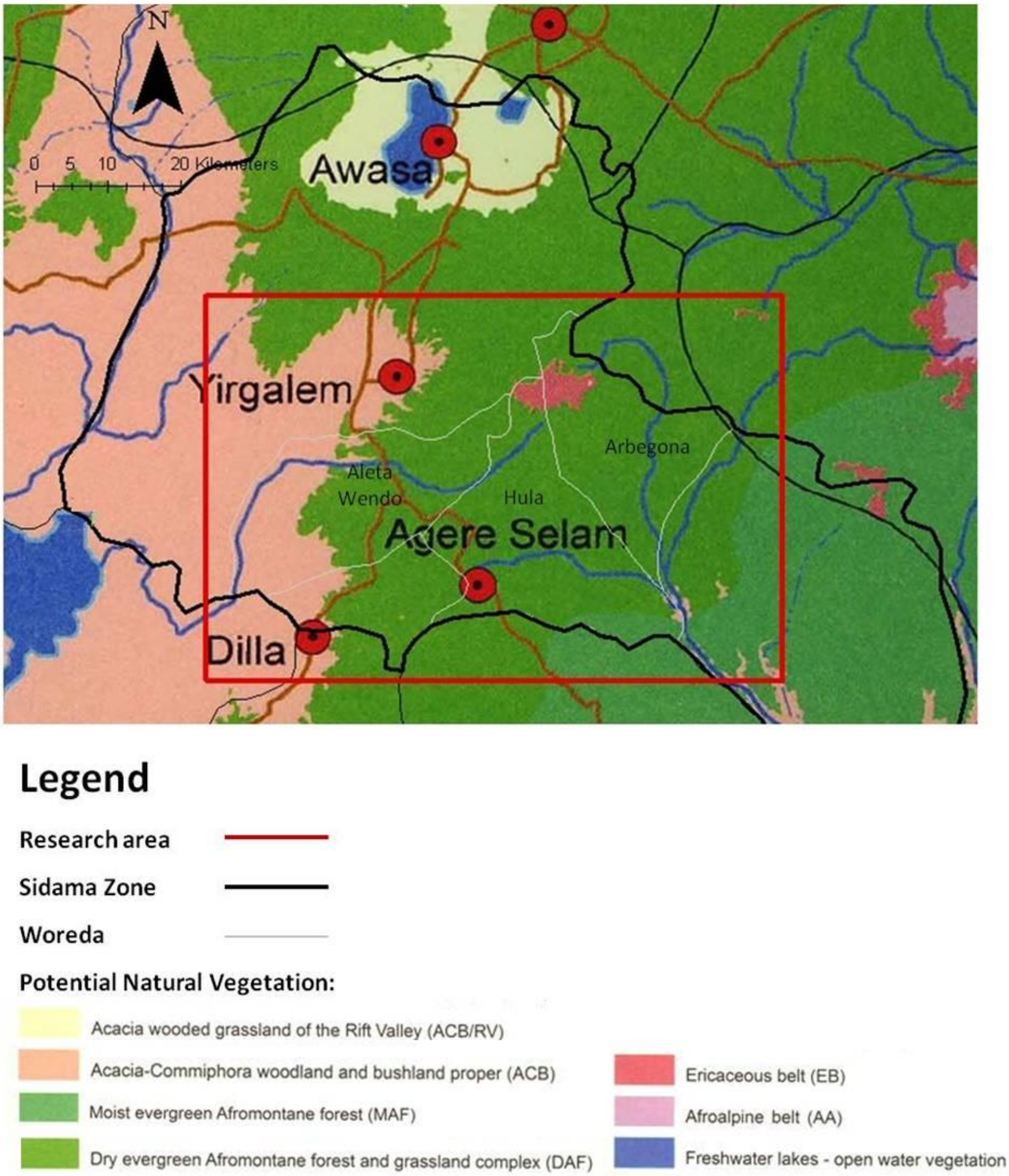

Fig. 18: Potential natural vegetation of the wider research area. Source: Meder 2011, based on FRIIS, DEMISSEW, BREUGEL 2010 and MAPLIBRARY 2011.

The ecosystem Dry Evergreen Montane Forest and Grassland Complex, which is typically found at an altitude between 1900 and 3300 m above sea level, is characterized by a mix of extensive grasslands rich in legumes, shrubs and trees and closed forests with canopies

of several strata. Forest areas are dominated by Tid/Gatira (*Juniperus procera*) and Zigba/Birbirsa (*Olea europaea* subsp. *cuspidata*). Nonetheless, forests have been diminished extensively due to intense human activity (one of the highest population and livestock density in the country) and the along going need for agricultural and grazing land as well as fuel wood and have been replaced by bush- and grasslands (INSTITUTE OF BIODIVERSITY CONSERVATION 2005). Evergreen scrub vegetation in this ecosystem thus occurs mostly as secondary growth after deforestation (FRIIS, DEMISSEW, BREUGEL 2010). In the high altitude area (> 3000 m above sea level) a small patch of the Ericaceous belt can be found, which is physiognomically characterized by shrubs and shrubby trees such as *Erica arborea*, *Erica (Phillipia) trimera* (both Ericaceae) and *Hypericum revolutum* (Guttiferae) as well as perennial subshrubs and herbs such as *Alchemilla haumannii* (Rosaceae), *Geranium arabicum* (Geraniaceae), *Senecio schultzii* (Asteraceae) and *Thymus schimperi* (Lamiaceae) and ferns particularly belonging to the genus *Polystichum* (Dryopteridaceae) (FRIIS, DEMISSEW, BREUGEL 2010). Furthermore Acacia-Commiphora woodland and bushland can be found in the low altitude regions of the Rift Valley in the western part of the wider research area whereas moist evergreen Afromontane forest prevails in the southeastern part at the eastern slopes of the Eastern Highlands (see fig. 18).

4.2.7 Agroecological Zones

As mentioned above, traditional agroecological zoning is classified by elevation. According to the topography of the wider research area, three different traditional agroecological zones can be found in the area. In the Eastern Highland parts, primarily in the woredas Arbegona and Hula, “Dega” is the prevailing zone. Towards the transition to the low altitude Rift Valley as well as towards the southeastern lowlands, “Woina Dega” is the prevalent zone. A small occurrence of “Kolla” can be found in the southwest of the wider research area (see fig. 19). In terms of the more detailed 18-classes agroecological zoning by the Ethiopian Ministry of Agriculture and Rural Development, which takes temperature and rainfall patterns as basis for classification, five different agroecological zones can be found throughout the wider research area. The prevailing agroecological zone in the wider research area is “tepid to cool humid mid highlands”, which covers extensive areas in the central, southern as well as most of the eastern part and is characterized by enset (*Enset ventricosum*, the so called “false banana”, is the traditional staple crop in southern Ethiopia) and cereal production. Both, Hula and Arbegona woredas are entirely within this zone. Towards the low altitude areas in the Rift Valley, the zoning becomes more heterogenic. While the short, but rather steep transition from the Eastern Highlands to the Rift Valley is characterized by “tepid to cool sub-humid lowlands”, which can also be found towards the north and northeast of the wider research area and is characterized by coffee and cereal production, and “hot to warm sub-humid lowlands”, characterized by tropical

fruit and cereal production, the northwest as well as a small part of the southeast classified as "tepid to cool moist mid highlands", characterized by cereal production. In the west, towards the southwest and, to a small amount in the southeast, "hot to warm sub-

Agroecological zones

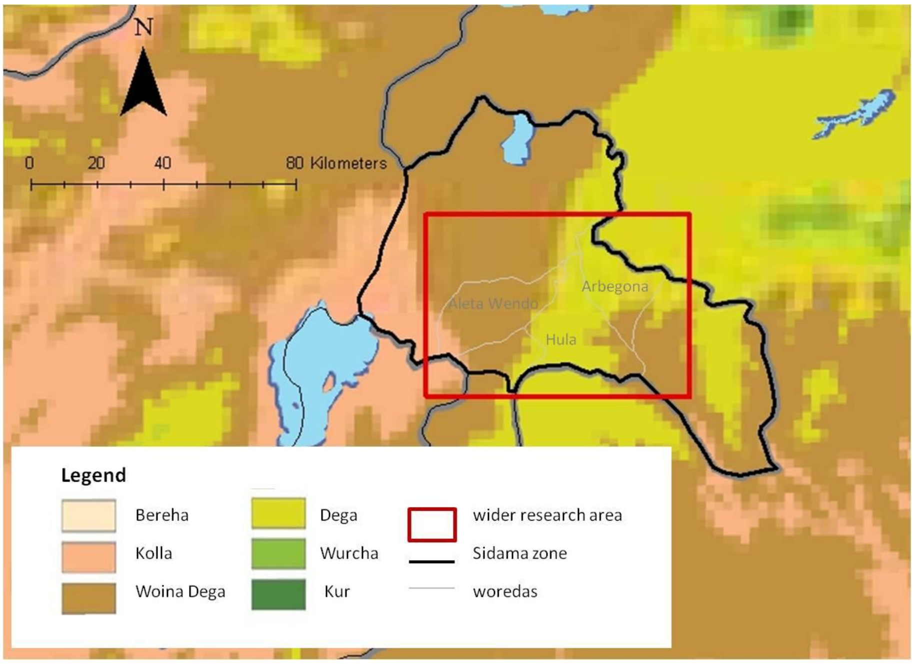

Fig. 19: Traditional agroecological zones. Source: Meder 2011, based on IFPRI, CENTRAL STATISTICS AGENCY 2006 and MAPLIBRARY 2011.

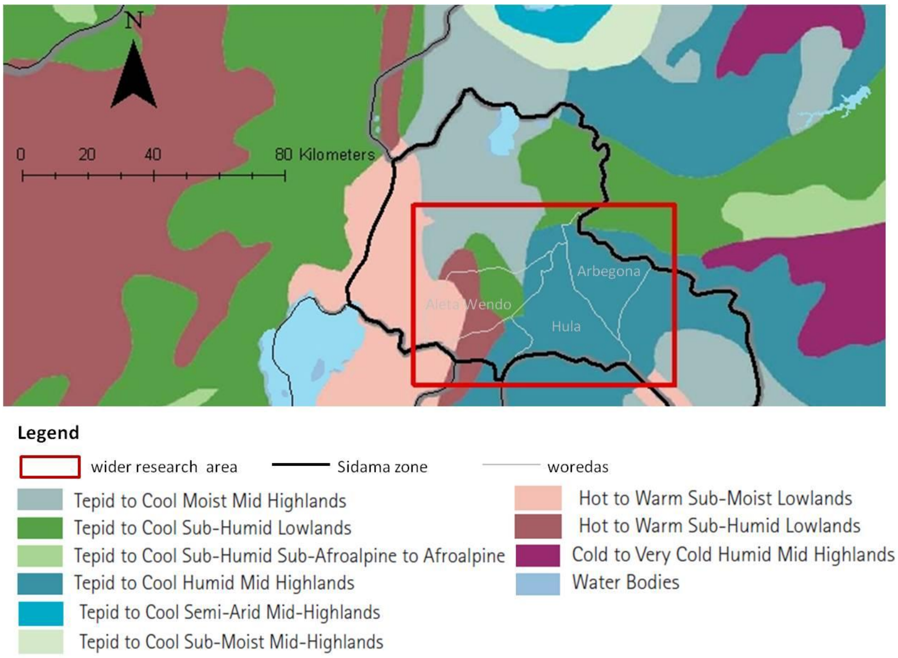

Fig. 20: Agroecological zones. Source: Meder 2011, based on IFPRI, CENTRAL STATISTICS AGENCY 2006 and MAPLIBRARY 2011.

moist lowlands" are prevailing, which is characterized by mixed farming dominated by cereals and tropical fruit production (IFPRI, CENTRAL STATISTICS AGENCY 2006; GTZ/SLM 2010) (see fig. 20).

4.2.8 Population and settlement

According to the 2007 census, the population size of the Sidama zone is 2,966,652, of which an estimated 849,506[14] live in the woredas Aleta Wendo, Arbegona and Hula. 92% of the latter are rural and 8% are urban residents (CENTRAL STATISTICS AUTHORITY 1996; POPULATION CENSUS COMMISSION 2008). With a population density of 520.85 people per km^2[15], the area is densely populated in national comparison.

Since no woreda based data was available, the data on ethnicity refers to the entire Sidama zone. According to the 1994 census[16], the zone's dominant ethnic group is Sidama with 88.6%, followed by 4.2% Amhara and 3% Oromo. The prevailing religions in the Woredas Aleta Wendo, Arbegona and Hula in 1994 were Protestant (59%) followed by traditional religions (24.1%), Ethiopian Orthodox Christian (6.6%), Muslims (3.8%) and Catholics (3.3%) (CENTRAL STATISTICS AUTHORITY 1996).

The economy of the Sidama zone is, just like the entire country's, based on agriculture. According to the World Bank, only 15.4% of Sidama's population is employed in non-agricultural positions (WORLD BANK 2004). Mixed agriculture (crop and livestock production) is practiced throughout the zone, in which traditional agroforestry systems with a diversity of perennial and annual crops are common. Major crops grown are enset, coffee, maize, wheat, teff, barley, haricot bean and khat while enset is the main staple crop in the highland area (LEMESSA 2002). There are two cropping seasons in the Sidama Zone, "Belg" and "Meher", which correspond with the rainy season "Belg" and "Kirmet" respectively. "Belg" rains are mainly used for land preparation and planting of

[14] Due to the restructuring of administrative boundaries in the Sidama zone as described in footnote 13, no population data for the former woredas Aleta Wendo, Arbegona and Hula was available in the 2007 census. Hence, population figures were estimated by taking into account the population growth of the entire Sidama zone population between the census 1994 and 2007 in order to multiply it with the 1994 population data of the three woredas to estimate woreda based population figures for 2007.

[15] Population density Aleta Wendo = 684.89 people/km^2, Arbegona = 442.6 people/km^2 and Hula = 423.49 people/km^2, based on the estimation described in footnote 14.

[16] Based on a total population of 2,044,836 (1994), contrasting the population of 2,966,652 in 2007 (CENTRAL STATISTIC AGENCY 2007).

long cycle crops such as maize and sorghum and seed bed preparation for “Meher” crops whereas “Meher” rains are used for planting of cereal crops such as barley, teff, wheat and vegetable crops. Furthermore, “Meher” rains are responsible for the growth of perennial crops such as enset, coffee and khat (LEMESSA 2002). The growing period, which, in this context, refers to the number of days with a mean daily temperature above 5°C and with available water in excess of half the potential evapotranspiration, amounts to 241 – 300 days (IFPRI 2006; CENTRAL STATISTICS AGENCY 2006). Main production problems are population pressure, land shortage and soil erosion. Nonetheless, farmers are/used to be self-sufficient and food-secure (LEMESSA 2002). As the land use/ land cover data of the zone shows, 50.67% of the zone’s total area is cultivated land, 17.57% grazing land, 6.51% forest, bushes and shrub land, 17.84 % cultivable, and the remaining 7.41% is covered by others (GEBREMESKEL 2011).

5. Methods

A variety of complementary methods was applied, chosen in line with the research objectives and the local conditions and resources available. In a first step, the environment assessment (EA) and watershed action planning (WAP) manual (Annex 1) and the corresponding questionnaire and checklist were developed. For this purpose, several expert interviews, a site visit as well as literature review was carried out. In a second step and in order to map the study area and assess its environmental state, a GPS based ground check as well as interviews with local farmers were conducted in order to fill in the questionnaire as well as the checklist mentioned above. Furthermore, it was drawn upon several topographic maps, satellite images as well as pre-existing GIS data sets from various sources.

5.1 Development of EA and WAP manual with questionnaire and checklist

In order to develop a manual and the corresponding questionnaire and checklist appropriate to note down all features of interest in the scope of an environment assessment of the research sites, varies methods were drawn upon. For this purpose, several expert interviews with representatives from the GIZ ECO as well as GIZ SLM program[17] were conducted. Furthermore a visit to one of the GIZ SLM sites in Ambo in the Oromia zone took place in October 2010. Literature regarding environment assessment, watershed management and Ethiopian environmental conditions was reviewed. The development of the manual and the corresponding questionnaire and checklist particularly draws upon the first and second part of the document "Community Based Participatory Watershed Development: A Guideline" (DESTA et al. 2005a; Desta et al. 2005b) (manual Annexes 3 and 4) published by the Ethiopian Ministry for Agriculture and Rural Development and contributions by WFP (World Food Program), ILRI (International Livestock Research Institute) and GIZ among others and the document "Micro Hydro Power Scout Guide: A Field Worker's Manual" (SCHNITZER 2009) (manual Annex 5), developed for GIZ ECO. The EA and WAP manual was particularly designed for the application in catchment areas with MHP schemes. For this purpose, general information on environment assessment and watershed management was narrowed down, emphasizing the connection to MHP implementation throughout the developed document. The manual was developed taking into account that its future users will only have access to limited working equipment. Thus the manual focuses on simple methods rather than recommending sophisticated tools such as GIS, DEMs and GPS units.

[17] GIZ's Sustainable Land Management (SLM) program (2005 – 2015) aims to reduce soil erosion through measures to rehabilitate watersheds, raising agricultural productivity by using appropriate production technologies and hence reach food security (GIZ 2011e).

5.2 GIS application

The mapping of the research sites was realized based on the Geographical Information System (GIS) software ArcGIS 9.2. On the basis of pre-existing river network, contour lines and catchment area GIS layers (EGGER 2010), all relevant spatial data, which was collected during the GPS-based ground check, the interviews with local farmers, the work with topographic maps as well as with satellite imagery (see below) was compiled and complemented. The pre-existing river network and catchment area GIS layers were altered according to the findings. For each research site, maps based on the coordinate system WGS 1984 (UTM zone 37N) were developed. ArcGIS 9.2 was furthermore used for area calculation and distance measurements.

Data on slopes and elevation were attained on the basis of pre-existing digital elevation models of the study area, abstracted from the report "Environment Assessment related to GTZ AMES-E Micro Hydro Power Projects" (EGGER 2010), a study previously prepared particularly for GIZ ECO on the research topic.

Data on land use and catchment area was collected from Cnes/SPOT and DigitalGlobe/QUICKBIRD (March 2003) satellite images from GOOGLE EARTH. The software was furthermore used for the determination of information on elevation and distances.

5.3 GPS based ground check and mapping

The field research was conducted in the "Bega" dry season (see chapter 4.2.3) between October 2010 and January 2011. Field trips were organized from Sidama zone's administrative center Awassa (see fig. 13). While all powerhouses were accessible by car, roads upstream of the Hagara Sodicha and the Gobecho I MHP plants were inaccessible by vehicle. Thus the entire ground check was conducted on foot, accompanied by an interpreter (local teacher and priest in the Gobecho and Hagara Sodicha catchment respectively) and various local farmers.

GPS data was collected with the GPS units Thales Mobile Mapper and Garmin CSx and was converted into ArcGIS compatible shape files using Thales Mobile Mapper and DNR Garmin software respectively.

In order to illustrate the delineation of watershed boundaries according to contour lines, the topographic map 0638 B3 "Arbe Gona" (1988) in the scale 1:50,000 was used. Moreover the topographic map was enlarged and a subsection was used to illustrate the establishment of a base maps to fill in the surveyed land use data according to the manual.

5.4 Discharge and rainfall data

Discharge and rainfall data was available at the GIZ ECO. Since no rainfall gauging station was located in either of the two research sites, data from three gauging stations nearby (Hagare Selam, Besadaye and Arbegona) for the years 2001 – 2007 was summed up in order to calculate the average monthly rainfall of the two pilot sites.

5.5 Interviews with local farmers

During the field visits, local farmers were interviewed. Interviewees were chosen by their function in the local community including farmers, elderly respect persons or administration functionaries. The qualitative interviews followed open questions and were conducted in order to gather as much information on natural and socio-economic topics of interest such as current and former land use and land cover as well as population development. In a second step, the findings were compiled and noted down in the environment assessment questionnaire and checklist.

5.6 Socio-economic data

Socio-economic data was not only determined by interviewing local farmers and GIZ ECO staff members, but was also abstracted from the baseline survey "Small Hydro Power – Access to Modern Energy Services Ethiopia (AMES-E)" (HASKAMP, KASSA 2010) and EGGER 2010. Both studies were particularly conducted for GIZ ECO on the pilot site villages Hagara Sodicha, Gobecho and Beshiro Gute (Ererte).

6. Environment Assessment (EA) and Watershed Action Planning (WAP) Manual

As mentioned in chapter 3, the GIZ ECO hydro component developed several best practice manuals, all of them addressing various topics related to MHP project implementation. In the framework of this paper, the manual dealing with environment assessment (EA) and watershed[18] action planning (WAP) (Annex 1) will be elaborated on. The manual and the corresponding questionnaire (manual Annex 1) and checklist (manual Annex 2) were developed in a way to make them applicable at grass root level, recommending simple and affordable tools. The full version of the EA and WAP manual can be found in Annex 1. The following depiction of the manual will strongly draw upon the manual text.

The objective of the EA and WAP manual is to include environmental matters in each GIZ ECO MHP implementation. It is crucial to take the environmental condition of the catchment area into account when implementing a MHP scheme, since the plant's sustainable use strongly depends on the continuous discharge of the river, which in turn is conditioned by the environmental state of the scheme's catchment area. The relation between environmental condition of the catchment area and the MHP plant is as follows: Since degradation might decrease the retention capacity of the soil, the discharge might be altered and thus the occurrence of the river drying out or flash flood events may increase. All of this negatively affects the sustainable use of the MHPs, since without a continuous discharge, sufficient and sustainable electricity supply cannot be provided permanently. Increased sediment load will moreover wear off the plants' turbines and thus reduce the durability of its equipment (see Annex 1). In order to warrant sustainable land use and hence sustainable electricity supply, it is of great importance to manage the catchment carefully, which includes two steps: environment assessment and watershed action planning.

The developed manual consists of six parts whereat parts 1, 2 and 3 were developed by the author and parts 4, 5 and 6 are pre-existing documents:
(1) a text part,
(2) a questionnaire (manual Annex 1) and
(3) a checklist (manual Annex 2),

[18] The term "watershed" is ambiguous: in American English the term refers to the entire area of a drainage basin whereas in British English it describes the drainage basin's outlines/divide. In the scope of this paper, the term "watershed" always refers to the drainage basin itself and not the drainage basin's outline. Thus, "watershed", "catchment" and "drainage basin" are used interchangeably.

(4) DESTA et al. (2005a): Part 1: Community Based Participatory Watershed Development: A Guideline (manual Annex 3)
(5) DESTA et al. (2005b): Part 2: Community Based Participatory Watershed Development: Annex (manual Annex 4) and
(6) SCHNITZER (2009): Micro Hydro Power Scout Guide: A Field Worker's Manual (manual Annex 5).

6.1 Part (1): Manual

Part (1) elaborates on the participatory approach as well as on the procedure of assembling a watershed planning team, environment assessment, causes and features of degradation and watershed action planning. For details, it is continuously referred to the manual's Annexes 3 to 5, which were particularly developed for watershed management in Ethiopia for the Ethiopian Government (manual's Annexes 3 and 4) and GIZ ECO (manual's Annex 5) respectively and thus contain detailed and more general information on environment assessment, watershed management and associated techniques which add on to the information provided in part (1) of the manual, which was primarily developed in the context of MHP catchments.

6.1.1 Participatory approach and identification of stakeholders

In the context of the establishment of a watershed planning team, the manual provides a description of the participatory approach, which is recommended to be the basic idea running through the entire application of the manual. The approach's core message is that all MHP stakeholders and the watershed communities should be involved in all steps of the planning and implementation as well as the monitoring and evaluation process, since taking into account people's needs helps to increase acceptance and thus their willingness to invest in long term conservation (see Annex 1). The manual then gives recommendations on how to establish a watershed planning team, taking into account stakeholders from various disciplines and different levels of administration.

6.1.2 Environment Assessment (EA)

This chapter of the manual provides information and recommendations on how to conduct an EA. As mentioned above, the manual was particularly designed for an application at grass root level, which also applies for the EA approach recommended in the document. Thus, the EA approach presented in the manual can be defined as a combination of landscape observation, interviews and mapping in order to assess as much environmental information as possible of the target area, while taking into account environmental as well as socio-economic features of the catchment area. Recommended tools are the application of the provided questionnaire and checklist (manual's Annexes 1 and 2) as well as the development of a base map on the basis of topographic maps, in order to map the findings

in the desired detail and scale. The manual recommends identifying major problems and problem areas based on the filled in questionnaire, checklist and developed maps and list them according to priority. Results of the environment assessment should be a list of the identified problems of the watershed ranked by priority as well as a map and/or several thematic maps, showing the watershed's environmental condition and problem areas.

The EA approach promoted in the manual is not to be confused with the term Environment Impact Assessment (EIA), or short Environmental Assessment, which the World Bank defines as "an instrument to identify and assess the potential environmental impacts of a proposed project, evaluate alternatives, and design appropriate mitigation, management, and monitoring measures" (WORLD BANK 1999). In the context of MHP projects, an Environmental Impact Assessment would thus focus on the impact the MHP project has on the condition of the environment, unlike the EA, which is the first step towards the development of a watershed action plan (see Annex 1) and assesses the impact of the environmental condition on the MHP project. Nonetheless, EA might be considered as part of EIA, since the latter includes a similar screening process.

6.1.3 Causes, features and effects of degradation

In order to emphasize and illustrate the relation between watershed degradation and sustainable use of the MHP plants, the manual gives an overview of causes, features and effects of degradation, providing information of their respective impacts on the MHP use.

6.1.4 Watershed Action Planning (WAP)

The WAP approach presented in the manual is particularly designed for the application in MHP catchments and an application at grass root level. In the scope of this paper, first a general definition of the term "watershed management" is given before elaborating on the WAP approach used in the manual.

The World Bank defines watershed management as "[…] the integrated use of land, vegetation and water in a geographically discrete drainage area for the benefit of its residents, with the objective of protecting or conserving the hydrologic services that the watershed provides and of reducing or avoiding negative downstream or groundwater impacts. The key characteristics of a watershed that drive management approaches are the integration of land and water resources, the causal link between upstream land and water use and downstream impacts and externalities, the typical nexus in upland areas of developing countries between resource depletion and poverty, and the multiplicity of stakeholders. Watershed management approaches need to be adapted to the local situation and to changes in natural resource use and climate" (DARGHOUTH et al. 2008).

Against the backdrop of this general definition, the WAP approach recommended in the manual consists of four parts, namely the identification of appropriate mitigation and intervention techniques, community's involvement in the implementation process, the implementation process itself as well as a participatory monitoring and evaluation part.
In a first step, it is recommended to identify appropriate mitigation and intervention techniques on the basis of the list of problems identified and ranked according to priority developed as an outcome of the EA and to draft an action plan. The manual provides exemplary mitigation techniques as well as examples of how rather simple intervention techniques can improve the environmental condition of the catchment while referring to the manual's Annexes 3 and 4 for details. In a second step, it is recommended to involve the community by presenting the draft plan to the people, taking their feedback and recommendations into account when wrapping up the final action plan. Here the manual also points to possibly occurring aspects of conflict as well as economic benefit. For the actual implementation process, the manual elaborates on responsibilities, training and finance issues which need to be considered. The manual recommends that, within the watershed action plan, the watershed planning team should lay down all commitments and responsibilities, including not only officials such as themselves but also the local population, as the contribution of the latter is not primarily of financial nature but rather the contribution of labor is their main investment to the implementation process (DESTA et al. 2005a). For this purpose, the manual furthermore recommends the conduction of training for local people participating in the implementation process in order to assure an appropriate realization of the mitigation techniques noted down in the action plan. In terms of financial matters it is moreover recommended to align the action plan individually with the budget of the respective MHP project and other financial sources such as the woreda's rural development office or the communities themselves. Finally, the manual also recommends applying the participatory approach in the monitoring and evaluation process, in order to make people, who are actively involved in the implementation process, more aware of how successful the implementation process is and in what way it needs to be altered (DESTA et al. 2005a). Furthermore it is emphasized to collect repeatable and thus comparable data in the process, choosing indicators adapted to the respective intervention techniques applied (see Annex 1).

6.2 Part 2: Questionnaire

Part (2), the questionnaire, was particularly developed to help noting down the data collected during the manual's in situ application of EA. The document includes a variety of questions with different answer modalities (ranging from qualitative to quantitative). Most of the questions are dealing with socio-economic aspects such as land use development and population. Explanations on how to fill in the different categories is

elaborated on in the document for each respective category. The questionnaire refers to manual's Annexes 3 – 5 for that purpose.

6.3 Part 3: Checklist

Like the questionnaire, part (3), the checklist, was particularly developed to help noting down the data collected during the manual's in situ application of EA. The checklist includes explanatory tables and matrixes in order to fill in the results, particularly focusing on environmental aspects such as degradation and current land cover. Green and red color signatures in the checklist's tables indicate whether the occurrence of a feature in the surveyed quantity and degree is to be considered positive (green) or negative (red).

7. Application of the EA and WAP manual

In the scope of this study, the developed EA and WAP manual is applied to two catchments of the GIZ ECO MHP pilot sites in the Sidama zone/SNNPR/Ethiopia, namely Gobecho I (and Gobecho II, see 7.1 for details) and Hagara Sodicha (see fig. 2).

Although the manual includes both, EA and WAP, **only the EA approach** will be examined in the scope of this paper. It should be noted that also the application of the EA part of the manual is modified from the actual procedure recommended in the manual since no watershed action team was established (the research was conducted by an individual researcher) and mapping work was primarily done GIS-based and not, as recommended, based on topographic maps due to time constraints. However, one topographic map-based hand-drawn watershed delineation and one example of a base map of a subdivision of the Gobecho catchment, which were developed according to the manual, can be found in Annex 6 and 7 respectively. GIS-based land use maps which summarize the findings can be found in Annexes 2 - 5. In terms of WAP, solely a recommendation for appropriate mitigation techniques is given (see chapter 9). The presentation of results for the two research sites will be carried out according to the EA questionnaire and checklist, which are annexes to the manual.

As recommended by the EA and WAP manual, each catchment was divided into an upstream and a downstream part in order to make results more detailed and to be able to clearly point differences in land use, land use practices and associated degradation features between not only the two research catchments but also between the up- and downstream parts of the latter. In this context it should be noted that other divisions are possible. An overview of each catchment will be given (according to the questionnaire), before the two subdivisions of the respective watershed will be presented in greater detail (according to the checklist). Additional and explanatory details on the results are primarily given in chapter 7.1.1 (Gobecho I downstream catchment), since this is the first of the four areas, results are presented for. The additional details do however apply to all four parts of the two catchments. Due to time constraints, the land use mapping especially focused on the water courses and spring areas. Thus only a certain percentage of the entire area was surveyed by ground check. The presented results refer to the actually surveyed area. It should be noted that data on some parts of the catchment, particularly on the western part of the upstream part of the Gobecho catchment, was retrieved from satellite data and lack detailed information on degradation features. Moreover, it was not possible to collect and analyze all data according to the questionnaire and checklist. Applied changes and reasons are elaborated on in the respective chapters.

7.1 Research site 1: Gobecho I (and II)

The two GIZ ECO pilot MHP sites Gobecho I and II (see fig. 22, 23, 24 and 25) are located in Gobecho kebele in Arbegona woreda (see fig. 2). Although both MHP plants are situated on Gange river (Gobecho I is located approx. 2.2 km upstream from Gobecho II), the study presented in this paper was conducted on the basis of the Gobecho I catchment area, which is approx. 181 ha smaller than the Gobecho II catchment (see fig. 21). However, since the two catchments overlap for more than 94%, the results as well as the recommendations given for Gobecho I can be applied to Gobecho II as well.

Location and catchment area The MHP power house Gobecho I is located at 6°35’29’’ N and 38°40’56’’ E and has a watershed area of 3082 ha (30.82 km^2) of which 1510.03 ha (49%) were surveyed. The catchment area is located between 6°35’29’’ N and 6°42’48’’ N as well as 38°36’20’’ E and 38°41’05’’ E (see fig. 2, fig. 21 as well as Annex 2 and 3).

Gobecho catchment and MHP plants Gobecho I and II

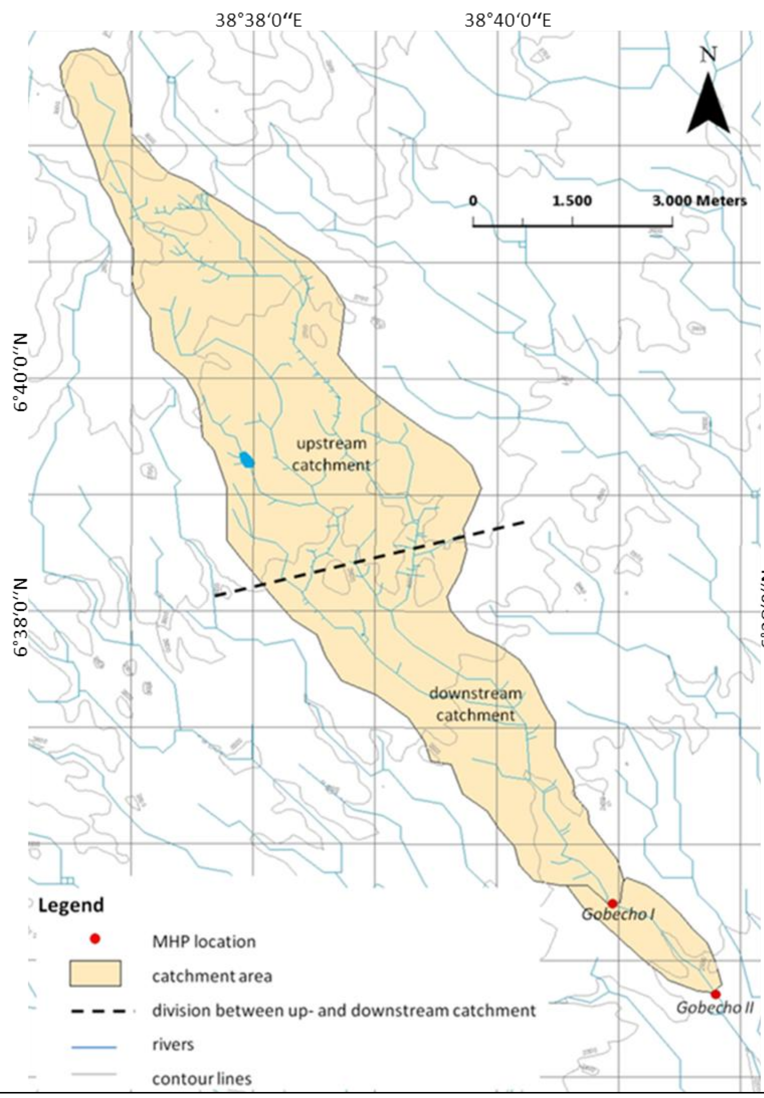

Fig. 21: Gobecho catchment and MHP plants Gobecho I and II. For more details see Annex 2 and 3. Source: Meder 2011, based on EGGER 2010.

MHP plants Gobecho I and II

Fig. 22: MHP plant Gobecho I: powerhouse. Source: Meder 2010.

Fig. 23: Waterfall the MHP plant Gobecho I is located on. Source: Meder 2010.

Fig. 24: MHP plant Gobecho II: powerhouse under construction. Source: Meder 2010.

Fig. 25: Waterfall the MHP plant Gobecho II is located on. Source: Meder 2010.

Topography The catchment's altitude ranges from 2,317 m above sea level at the power house and 3,050 m above sea level in the headwater region (see Annex 2 and 3). In general, the catchment is of moderate topography with an inclination of up to 15° (EGGER 2010). It is characterized by the alternation of flat valley floors and hills with rounded tops, which gives the catchment an undulated appearance. Towards the headwater regions, at an altitude of approx. 2,800 m above sea level, the inclination increases. The prevailing valley types in this part of the catchment are V-shaped valleys.

Hydrology The catchment's drainage pattern shows features of a dendritic as well as of a parallel pattern (see Annex 2 and 3). Dendritic patterns have a treelike arrangement of small tributaries in the headwaters that flow in a variety of directions and continually join to eventually form the major stream. Dendritic patterns are common on erodible sediments with no unusual geological features and adequate rainfall. Parallel patterns are essentially an elongated form of the dendritic pattern and indicated the prevalence of a

steep regional slope (DEBARRY 2004). While dendritic features are prevailing in the less inclined areas in the middle part of the watershed (see Annex 2), parallel features can be found for example in the headwater region above 2,900 m above sea level (see Annex 3). Particularly in the less inclined middle part of the catchment area with flat gradient, meandering was frequently detected. In general, particularly major stream branches were occasionally interrupted by small waterfalls and cascades. Gange river can be classified as a perennial stream. However, seasonal alternations, correlating with the rainy and dry seasons, occur (see fig 26)[19]. According to local sources, a couple of small tributaries dry up towards the end of the Bega season (dry season between October and February, see fig. 16).

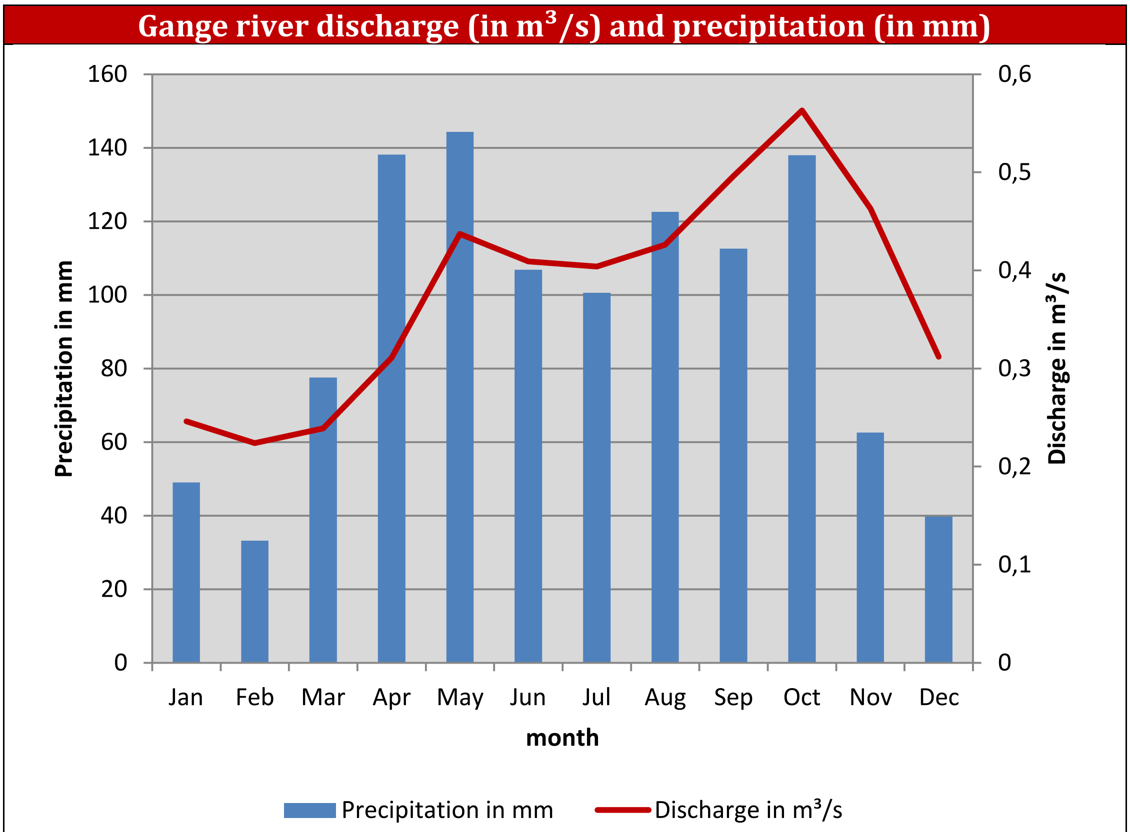

Fig. 26: Average monthly precipitation at the gauging stations Bensadaye, Arbegona and Hagere Selam (in mm) (survey period 2001 - 2007) and monthly discharge of Gange river (in m^3/s) (survey period unknown). Source: Meder 2011 based on GIZ ECO staff information.

[19] When interpreting fig. 26, it should be kept in mind that neither long term rainfall data was available for the research site, nor the discharge survey period is known. Hence the shown correlation between precipitation and rainfall is solely to be understood as a rough guideline.

Agroecological zone The entire Gobecho I catchment is located in the agroecological zone “tepid to cool humid mid highlands”, which is characterized by enset and cereal production. In terms of traditional agroecological zoning, the only prevalent zone is “Dega” (see fig. 27).

Agroecological zones in the Gobecho and Hagara Sodicha catchment

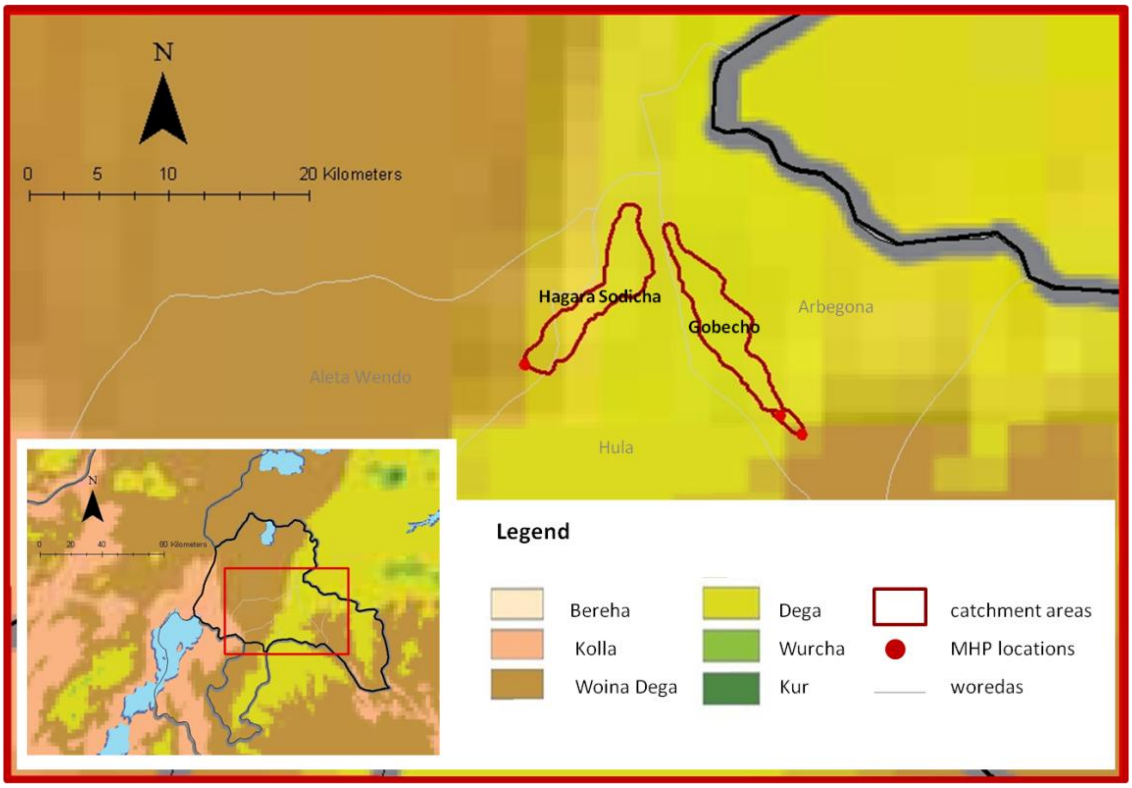

Fig. 27: Traditional agroecological zones in the Gobecho and Hagara Sodicha catchment. Source: Meder 2011 based on IFPRI 2006; CENTRAL STATISTICS AGENCY 2006 and MAPLIBRARY 2011.

Population The current population of the catchment is approximately 6,000. Thus, the current population density is approx. 195 people per km^2, which is significantly less than the woreda’s population density of 442.6 people per km^2 (see footnote 15). According to local sources, the population figures are rising due to a high fertility rate. Currently, the distribution of human settlement in the catchment area is comparably balanced, not taking into account agglomerations around market areas. However, a population growth around the powerhouse is likely to occur once the MHP is implemented.

Land use changes According to local sources, the catchment area was initially settled approx. 40 years ago. Before that, the entire catchment was said to be widely covered with natural forest population. Once people started to settle in the area, most of the natural forest was cut down not only for firewood and timber extraction, but also to transform the land for cultivation and pastoral purposes. Today, the catchment is intensively used by agriculture and pasture. Forest primarily occurs in form of reforested, homogenous patches which are used for fire wood and timber extraction. For detailed information on today's land use, see chapters 7.1.1 and 7.1.2. Since land is traditionally split between all heirs within a family, an increasing fragmentation of land ownership and thus land is likely to occur, especially since population figures are raising and polygamy is practiced in the area - 10 to 20 children per farmer are common. Due to the associated land shortage, people increasingly move into less favorable places within the catchments, such as steep hillsides, which have not been populated before due to their inaccessibility and/or incompatibility for farming and clear the trees for agricultural purposes (HASKAMP, KASSA 2010). As mentioned earlier, a population growth around the MHP is likely to occur, which also will affect the land use in areas adjacent to the thereby newly established agglomeration.

7.1.1 Gobecho I downstream area

The downstream part of the Gobecho I catchment has a total area of 1127 ha (11.27 km^2) of which 587.09 ha (52.09%) were surveyed. Its elevation ranges from approx. 2,317 m above sea level to approx. 2,600 m above sea level (see Annex 2).

7.1.1.1 Land use/land cover

In the downstream part of the Gobecho I catchment the prevailing land use is grazing and the cultivation of permanent and seasonal crops. The respective land uses cover 271.26 ha (46.2%), 130.48 ha (22.22%) and 124.01 ha (21.12%) of the surveyed area. Wetland occurrence primarily overlaps with grazing areas. With an area of 19.51 ha, the detected grass wetlands account for 7.19% of the grazing areas and 3.32% of the total downstream catchment. Forest and bush land, on the other hand, only account for 53.35 ha (9.09%) and 7.99 ha (1.36%) respectively (see fig. 28 and Annex 2).

Gobecho downstream catchment: share of land use/land cover in %

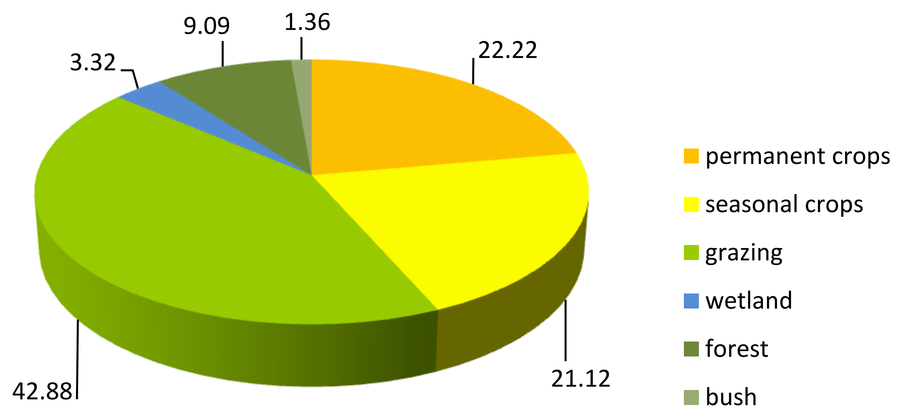

Fig. 28: Gobecho downstream catchment: share of land use/land cover in %. Data refers to the actually surveyed area. Source: Meder 2011.

According to the checklist classification, the grazing occurrence as well as the extent of seasonal and permanent crop cultivation is high while forest and bush land occurrence can be classified as low. Wetland occurrence is medium.

Agriculture In general, the downstream part of the Gobecho catchment is intensively used by agriculture. The land use pattern features a dense distribution of cultivation plots on the slopes with maize (*Zea mays)* as principal crop (see fig. 29), followed by teff

(*Eragrostis tef)*, barley (*Hordeum vulgare*) and horse beans (*Vicia faba*). Partially, cultivation plots reach till the waterways in the valley grounds. While maize is cultivated throughout the downstream basin, teff cultivation decreases with increasing altitude. Teff was found to be cultivated up to an altitude of approx. 2,500 m above sea level. Barley cultivation, on the other hand, increases with increasing altitude. Barley becomes the principal crop above an altitude of 2,600 m above sea level. Enset (*Enset ventricosum*), the so called "false banana", is the principal permanent crop cultivated in the area and can mainly be found on the hilltop areas (see Annex 2).

Grazing land was particularly found along waterways and thus in valley areas. Nonetheless some grazing areas are located in between cultivation plots. The latter can often be found adjacent to settlements. Particularly in the upper part of the downstream catchment, grazing land becomes more prevalent and can also be found on slopes (see Annex 2). Moreover a bias between fodder and no-fodder plants was detected (see fig 30).

Cropping and Grazing land in the the downstream Gobecho catchment

Fig. 29: Maize cultivation in the downstream Gobecho catchment. Source: Meder 2011.

Fig. 30: Grazing land in the upper part of the downstream Gobecho catchment. Source: Meder 2011.

Forest and bush Only accounting for 10.45% of the total area surveyed, forest and bush characterize the downstream catchment only subordinately. Forest occurrence can be found on hillsides and partially along water ways and around springs (see Annex 2). The prevailing forest type is highland bamboo (*Yushania alpina*), which mostly grows in a homogenous composition (see fig. 31). According to local sources, the identified populations are at least partially reforested and are used for timber and fire wood

extraction. Furthermore, a few plots with a combination of bamboo and eucalyptus (*Eucalyptus*[20]) were found. Other than that, only few spots of mixed vegetation with various indigenous plants were detected during the field visits. Nonetheless, nearly all of those include bamboo and/or the exotic eucalyptus and were primarily located along water ways.

Bamboo occurrence in the downstream Gobecho catchment

Fig. 31: Bamboo occurrence in the downstream Gobecho catchment (left and central background). Source: Meder 2010.

Isolated indigenous trees can be found throughout the downstream part of the catchment, often integrated in cultivation areas. Except bamboo and eucalyptus, individual species could not be identified due to translation difficulties. Throughout the downstream part of the catchment in-line planted succulents and eucalyptus trees can be found as fences around and/or between cultivation and grazing plots. Furthermore, the latter was frequently spotted to occur along water ways.

Springs, wetlands and waterways Wetlands can be found on grazing areas and mostly occur around springs or along water ways in flat terrain in the upper part of the downstream catchment (see Annex 2). All wetlands detected are grass wetlands featuring hydrophilic sedge grasses (EGGER 2010) (see fig. 32). A total of 29 springs were detected in the downstream part of the Gobecho catchment, which equals an average number of 4.9 springs per km^2 and a high occurrence according to the checklist. 8 springs were found to be protected by forest and 5 by bush cover. Thus 44.83% of springs have a

[20] Individual species could not be identified due to translation constraints.

vegetation buffer[21] whereas 55.17% are located on grass covered areas. The prevailing species in spring areas was found to be bamboo, which mostly occurs in homogenous composition. The total length of the stream net in the downstream part of the Gobecho catchment is 21,148.33 m, of which 16,471 m and thus 77.88% were surveyed.

Vegetation buffer stripes were found to occur along a total of 3,900 m of water courses (23.68% of the total length surveyed, equaling a low occurrence according to the checklist) whereas 12,571 m (76.32%, equaling a high occurrence according to the checklist) of surveyed stream length was found to have no buffer stripes (see fig. 33 as well as Annex 2). Vegetation buffers are composed of bamboo and/or eucalyptus. However, in some areas, a mixed composition of various indigenous tree and bush species were detected. Nonetheless, the latter almost always included at least single bamboo or eucalyptus trees.

Wetland and unbuffered waterway in the downstream Gobecho catchment

Fig. 32: Grass wetland in the downstream Gobecho catchment. Source: Meder 2010.

Fig. 33: Unbuffered waterway in the downstream Gobecho catchment. Source: Meder 2010.

[21] In the scope of this study, and thus applying to all for parts of the research sites, the term "vegetation buffer" refers to all types of forest and bush vegetation, not taking into account whether the respective areas are composed homogeneously or heterogeneously and/or of indigenous or exotic species. It does not include grass cover, enset cultivation and in-line planted eucalyptus or bamboo trees along river courses.

7.1.1.2 Land use practices

In the downstream part of the Gobecho catchment, all cultivation was found to be rain fed, *irrigation* is not applied. *Drainage* was found to be applied on two adjacent spots located in a wetland area in the upper part of the downstream catchment (see Annex 2). Draining is applied in form of small channels with a diagonal of approx. 30 cm (see fig. 34). The measures are implemented in order to improve the site conditions for crop cultivation.

Drainage application in the downstream Gobecho catchment

Fig. 34: Drainage application in the downstream Gobecho catchment. Source: Meder 2010.

No information on the application of *slash and burn* practices or *rotational land use* practices could be collected during the field visits.

7.1.1.3 Occurrence of degradation forms

Two *landslides* with the magnitudes 10 x 2 m and 15 x 10 m respectively were detected in this part of the Gobecho catchment. With an average extent of 85 m^2 and an average quantity of 1.7 per 5 km^2 the ascertained degree of landslide degradation is high according to parameters in the manual. Both landslides were detected to be located in the upper part of the slope close to the hilltop on grazing and crop land (see fig. 35 and Annex 2). One landslide is located in the upper and one in the lower part of the downstream catchment.

Landslide in the downstream Gobecho catchment

Fig. 35: Landslide in the downstream Gobecho catchment. Source: Meder 2010.

In order to determine the extent and degree of *cattle step* in the catchments, the EA checklist suggests collecting data on the respective spatial extent as well as on the vegetation cover of the affected areas. In the scope of this study, the extent of cattle step could not be determined in the recommended way due to time constraints. It was however surveyed by occurrence, which means the areas affected by cattle step were marked in the map without any extra information on spatial extent. It should be noted that immense differences were found in the extent of respective areas affected by cattle step. Thus, particularly the average number of occurrence per km^2 is only to be understood as a guideline since cattle step extent can cover large areas although only detected in few but extensive plots. Vice versa, many small plots and thus a high occurrence per km^2 might only refer to a comparatively small total area actually affected by cattle step. In terms of vegetation density however, it was differentiated between areas with closed grass cover and areas featuring bare soil.

In the downstream part of the Gobecho catchment, a total of 40 spots affected by cattle step were surveyed. This equals an average occurrence of 6.81 per km^2. Cattle step was found to occur solely on grazing land on hillsides (the average number of spots affected by cattle step per 1 km^2 grazing land is 14.75) (see Annex 2). Most areas featured a closed grass cover, however 9 spots featuring bare soil were detected during the field survey. In general the number of spots affected by cattle step ascends with increasing altitude. While only scattered small-sized plots were detected in the lower part of the downstream

catchment, coherent and rather extensive areas were detected in the upper part of the catchment. Particularly in the upper part, cattle step was also found to occur around springs and wetland areas.

No *gully erosion* and *badland* features where detected in this part of the catchment area.

A total of 3 *river bank erosion* occurrences were discovered in the downstream part of the catchment which equals an average quantity of 2.56 per 5 km^2. The ascertained degree of river bank erosion is high. Two of the detected erosion spots were found to be located adjacent to grazing areas whereas the third was located in a wetland area.

No *sheet and splash erosion* was detected during the field visits.

7.1.1.4 Mitigation techniques

One example of *terracing* can be found in the upper part of the downstream catchment area which is used for cereal cultivation (see fig. 36 and Annex 2).

Mitigation measures in the downstream Gobecho catchment

Fig. 36: Terracing in the downstream Gobecho catchment. Source: Meder 2010.

Fig. 37: Agroforestry in the downstream Gobecho catchment. Source: Meder 2010.

Furthermore, the area is characterized by the extensive application of *fencing of plots.* The cultivation and grazing plots are mostly fenced by braided fences made of bamboo (see fig. 38), in-line planted cactuses of medium height (see fig. 39), in-line planted eucalyptus trees (see fig. 40) or a combination of the latter. However, in the scope of this study, it could neither be determined since when fencing is applied nor whether it is actually

applied for mitigation purposes or solely to delimit property boundaries. Application of fencing is not shown in the land use and degradation maps (Annexes 2 – 5).

Different types of fences

Fig. 38: Braided bamboo fence. Source: Meder 2011.

Fig. 39: In-line planted succulent fencing. Source: Meder 2011.

Fig. 40: In-line planted eucalyptus tree fencing. Source: Meder 2011.

8 *springs* are protected by forest and 5 by bush cover. However it is unclear whether the vegetation was preserved as a mitigation measure. For the prevailing vegetation composition, see chapter 7.1.1.1. *Agroforestry* is practiced in this part of the Gobecho catchment (see fig. 37). As mentioned above, isolated perennial trees can be found throughout the downstream part of the catchment, which are often integrated in cultivation areas. It is however undetermined if the trees were not cut down for agroforestry purposes, as it is unknown whether the know-how of this measure exists among the famers in the area. Like the application of fencing, agroforestry occurrence is not shown in the land use and degradation maps (Annexes 2 – 5). Other than that, no mitigation techniques were observed during the field survey.

7.1.2 Gobecho I upstream area

The upstream part of the Gobecho I catchment has a total area of 1,955 ha (19.55 km^2) of which 922.94ha (47.21%) were surveyed. Its elevation ranges from approx. 2,600 m above sea level to 3,050 m above sea level (see Annex 3).

7.1.2.1 Land use/land cover

The upstream division of the Gobecho I catchment is widely used for grazing. The latter extents over an area of 605.56 ha and thus accounts for 65.61% of the surveyed area. Permanent crops are cultivated on 142 ha (15.39%) while seasonal crops are cultivated on 95.45 ha (10.34%). With an area of 38.03 ha, grass wetlands account for 6.28% of the grazing area and for 4.12% of the entire upstream catchment area. Forest and bush land account for 67.43 ha and 12.5 ha and thus for 7.31% and 1.35% respectively (see fig. 41 and Annex 3).

Gobecho upstream catchment: share of land use/land cover in %

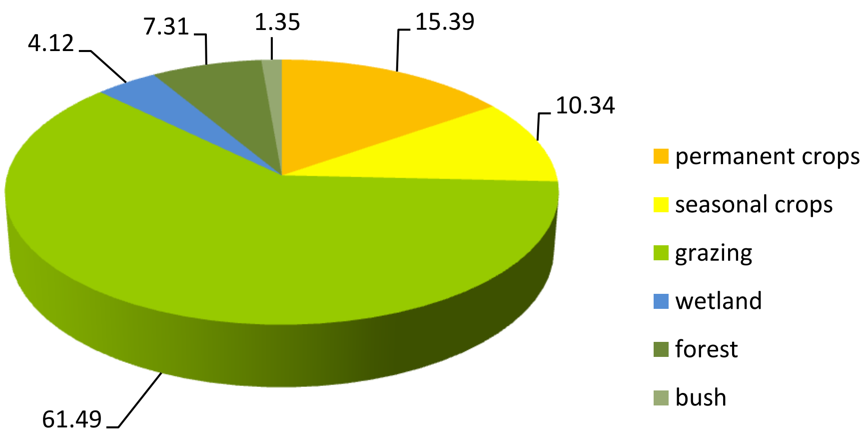

Fig. 41: Gobecho upstream catchment: share of land use/land cover in %. Data refers to the actually surveyed area. Source: Meder 2011.

The results of the checklist classification thus show a high occurrence of grazing area, a medium occurrence of seasonal and permanent crops and a low occurrence of forest and bush land. The occurrence of wetlands can be classified as medium.

Agriculture Cultivation of seasonal and permanent crops is practiced up to an altitude of approx. 2,900 m above sea level and can be found on slopes and on hilltops (see Annex 3). While maize is only cultivated up to an altitude of 2,650 m above sea level, which is equivalent to the lowest third of the upstream basin, barley cultivation becomes more

prevalent in areas between an altitude of 2,600 m and 2,850 m above sea level. Beans are cultivated up to an altitude of approx. 2,700m above sea level, but the extent of cultivation decreases significantly with increasing altitude. No teff cultivation is practiced in the upstream part of the Gobecho catchment. Enset cultivation, which is, just like in the downstream part of the basin, primarily practiced in hilltop areas, extends to an altitude of 2,850 m above sea level (see fig. 42).

Grazing In the upstream part of the Gobecho catchment, wide areas are used for grazing. Unlike in the downstream part of the catchment, grazing areas do not only cover areas along the waterways, but also extend to slopes and hilltops. Furthermore, the plots are more extensive and coherent (see fig. 43 and Annex 3). While in the lower part of the upstream catchment, pastoral alters with agricultural use, it becomes the prevailing land use with increasing altitude. Above 2,900 m above sea level, grazing is the only land use practiced. In various spots, a bias between fodder and non-fodder grass species was detected on grazing areas.

Mixed land use and grazing in the upstream Gobecho catchment

Fig. 42: Mixed land use in the lower part of the upstream Gobecho catchment. Source: Meder 2010.

Fig. 43: Grazing in the upper part of the upstream Gobecho catchment. Source: Meder 2010.

Forest and bush The prevailing forest type in the upstream part of the Gobecho catchment is bamboo, followed by eucalyptus. Both types primarily occur as homogenous, reforested plots around springs and water courses, and are used for timber and fire wood extraction (see fig. 42 and 44). Furthermore, a few plots with a combination of bamboo and eucalyptus were detected. Other than that, only few spots of mixed vegetation with various indigenous plants were found during the field visits. Nonetheless, nearly all of

those include bamboo and/or the exotic eucalyptus. Regardless their composition, most of the forest and bush plots can be found either around springs, along water courses or on hilltops, altering with enset cultivation (see Annex 3). Throughout the upstream part of the catchment, in-line planted eucalyptus as well as succulents and, less common, bamboo trees can be found along waterways. Less frequent, the latter can also be found as fences around and/or between cultivation and grazing plots (see fig. 43). These tree occurrences are not shown in Annex 3. In the catchment part above 2,900 m above sea level, no forest but rather scattered bush vegetation can be found. No spots of natural forests were detected during the field survey.

Bamboo and eucalyptus occurrence in the upstream Gobecho catchment

Fig. 44: Bamboo and eucalyptus occurrence in the upstream Gobecho catchment. Source: Meder 2010.

Springs, wetlands and waterways Wetlands can primarily be found on grazing areas and most often occur around springs or along water ways in flat terrain (see Annex 3). All wetlands detected are grass wetlands which often feature hydrophilic sedge grasses (see fig. 45). A total of 102 springs were surveyed in the upstream part of the Gobecho catchment, which equals an average number of 11.05 springs per km^2 and a high occurrence according to the checklist. 44 springs were found to be protected by forest and 4 by bush cover. Thus 47.05% of springs have a vegetation buffer whereas 52.95% are located on grass covered areas (see fig. 45). The prevailing species in spring areas was found to be bamboo (see fig. 46), which either occurs in homogenous composition or mixed with eucalyptus. The total length of the stream net in the upstream part of the Gobecho catchment is 41,660.03 m, of which 34,201 m and thus 82.1% were surveyed in

the scope of this study. Vegetation buffer stripes were detected along a total of 1,957 m of water courses, accounting for only 5.72% of the surveyed total of the upstream part of the catchment and thus for a low occurrence according to the checklist. No vegetation buffers were found along 32,244 m (94.28%) of water courses, which equals a high occurrence according to the checklist (see Annex 3).

Wetlands and springs in the upstream Gobecho catchment

Fig. 45: Grass wetland and unprotected spring in the upstream Gobecho catchment. Source: Meder 2010.

Fig. 46: Spring with bamboo cover in the upstream Gobecho catchment. Source: Meder 2010.

Vegetation buffers are composed of bamboo and/or eucalyptus. However, in some areas, a mixed composition of various indigenous tree and bush species was detected. Nonetheless, the latter almost always included at least single bamboo or eucalyptus trees.

7.1.2.2 Land use practices

All cultivation is rain fed, *irrigation* is not applied. *Drainage* application was found twice in wetland areas in the upstream part of the Gobecho catchment in order to improve site conditions for crop cultivation (see Annex 3). Draining is applied in form of small channels with a diagonal of approx. 20 cm (in upstream part) and 40 cm (in downstream part) (see fig 47).

Drainage application in the Gobecho upstream catchment

Fig. 47: Drainage application in the Gobecho upstream catchment. Source: Meder 2011.

No information on the application of *slash and burn practices* or *rotational land use* practices could be collected during the field visits.

7.1.2.3 Occurrence of degradation forms

All together 11 *landslides* were detected in the upstream part of the Gobecho catchment with magnitudes of 10 x 1 m (two times), 10 x 2m, 10 x 3m, 10 x 4m, 10 x 5m, 8 x 1m and 5 x 1m (four times). With an average extent of 17.09 m^2 and an average quantity of 5.96 per 5 km^2 the ascertained degree of landslide degradation is medium. All landslides detected were found to be located on grazing land, often close to cattle step occurrence (see Annex 3). Unlike the landslides found in the downstream part the extents of individual landslides are smaller in this part of the catchment and are mostly located in the lower part of slopes.

98 areas of *cattle step* occurrence have been surveyed in this part of the Gobecho catchment. The average number of spots affected by cattle step is 10.62 spots per km^2. Cattle step was found to occur solely on grazing land on hillsides (the average number of spots affected by cattle step per 1 km^2 grazing land is 16.18). Most areas featured a closed grass cover however, 21 spots featuring bare soil were detected during the field survey (see fig. 48 and 49). Cattle step occurrence is rather balanced and can be found throughout the upstream basin. Almost all grazing areas feature cattle step. Thus the degradation feature characterizes coherent and rather extensive areas and occurs in a particularly high degree along commonly used cattle paths. The latter were found to feature gully-like appearance at some points (see fig. 43). Cattle step was furthermore repeatedly found to occur around springs and adjacent to wetland areas (see Annex 3).

Cattle step and river bank erosion in the Gobecho upstream catchment

Fig. 48: Cattle step and river bank erosion in the upstream Gobecho catchment. Source: Meder 2010.

Fig. 49: Cattle step in the upstream Gobecho catchment. Source: Meder 2010.

Except for the gully-like cattle paths, no *gully erosion* and *badland* features where detected in this part of the catchment area (see "cattle step" section above).

A total of 10 *river bank erosion* occurrences were detected in the upstream part of the catchment which equals an average quantity of 5.42 per 5 km^2. The ascertained degree of river bank erosion is high. 7 of the detected erosion spots were found adjacent to grazing areas (see fig. 48) whereas 3 were located in wetland areas. 8 out of 10 erosion spots were detected in the lower part of the upstream catchment (see Annex 3).

No *sheet and splash erosion* was detected during the field visits.

7.1.2.4 Mitigation techniques

Four examples of *reforestation* were observed in this part of the Gobecho catchment. One reforestation project was implemented to rehabilitate a landslide (see fig. 50), two others were implemented on areas heavily affected by cattle step (see Annex 3). Reforested species could not be identified in the scope of this study due to translation constraints. The fourth, and most extensive reforested area detected is located on a rather steep slope with adjacent plots featuring cattle step. The area was reforested with eucalyptus (see fig. 51). Nonetheless it is unclear whether it was actually implemented in order to protect the

area from degradation or whether it was implemented in order to use the trees as timber and/or firewood.

Reforestation in the Gobecho upstream catchment

Fig. 50: Reforestation of a landslide in the Gobecho upstream catchment. Source: Meder 2010.

Fig. 51: Eucalyptus reforestation in the Gobecho upstream catchment. Source: Meder 2010.

In general it should be noted, that as mentioned above, a large amount of forest patches found in the catchments are reforested for timber and fire wood purposes. Since this chapter deals with applied mitigation techniques which are implemented in order to decrease the impact of degradation, these afforested areas were not taken into account in the scope of surveying mitigation techniques. It should be noted, however, that afforested plots might decrease uncontrolled deforestation in other areas of the watershed.

Furthermore, the area is characterized by the wide application of *fencing of plots.* The cultivation and grazing plots are mostly fenced by succulents of medium height, in-line planted eucalyptus trees or braided fences made of bamboo (see fig. 42, 43, 48 and 49 as well as 38 - 40). However, in the scope of this study, it could neither be determined since when fencing is applied nor whether it is actually applied for mitigation purposes or solely to delimit property boundaries. 44 *springs* were found to be protected by forest and 4 by bush cover. It is unclear, however, whether the vegetation was preserved as a mitigation measure. For the prevailing vegetation composition, see 7.1.2.1. No further mitigation techniques were observed in this part of the catchment area.

7.2 Research site 2: Hagara Sodicha

The GIZ ECO pilot MHP site Hagara Sodicha (see fig. 53 and 54) is located on Lalta river in Hagara Sodicha kebele in the woredas Aleta Wendo (powerhouse) and Hula (majority of the catchment area) respectively (see fig. 2).

Location and catchment area The powerhouse Hagara Sodicha is located at 6°37’26’’N, 38°31’5.3’’ E and has a watershed area of 3132ha (31.32km^2), of which 2604.09ha (83.14%) were surveyed. The catchment area is located between 6°37’26’’N and 6°43’55’’ N as well as 38°36’0’’ E and 38°31’10’’ E (see fig. 52).

Hagara Sodicha catchment and MHP plant

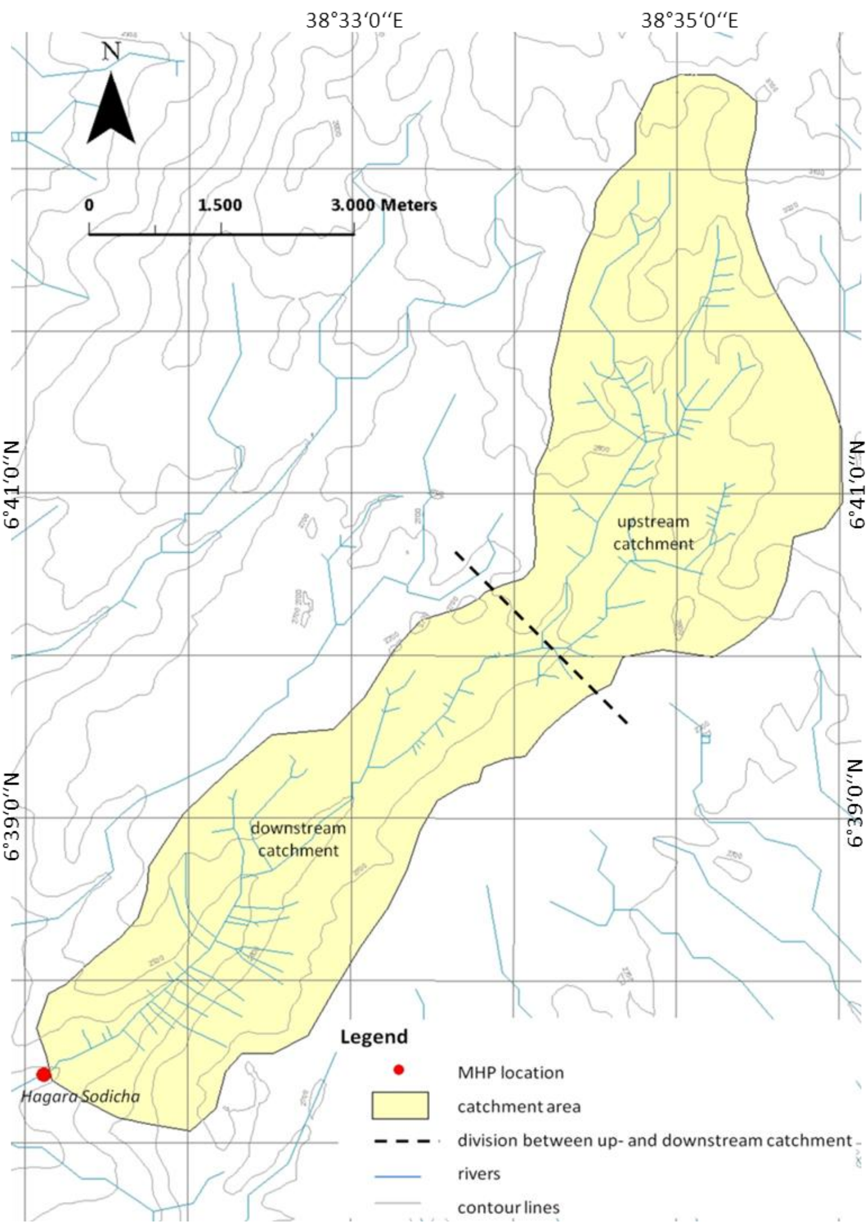

Fig. 52: Hagara Sodicha catchment and MHP plant. For more details see Annex 4 and 5. Source: Meder 2011 based on EGGER 2010.

MHP plant Hagara Sodicha

Fig. 53: MHP plant Hagara Sodicha: powerhouse. Source: Meder 2010.

Fig. 54: Waterfall the MHP plant Hagara Sodicha is located on. Source: Fasikaw Dessie 2009.

Topography The altitude ranges from 2,260 m above sea level at the power house and 3,100 m above sea level in the headwater region. The downstream part of the catchment is characterized by a V-shaped valley with steep slopes and an inclination of up to 35° (EGGER 2010) (see Annex 4). Above an altitude of approx. 2,600 m above sea level, the topography becomes less inclined and is characterized by round-top hills of moderate elevation and wide valley floors. Towards the headwater regions, particularly above an altitude of 2,800 m above sea level, inclination increases (see fig. 52 and Annex 5). Prevailing valley types are V-shaped valleys whereas hilltops are rounded.

Hydrology The catchment's drainage pattern shows features of a dendritic as well as of a parallel pattern (see chapter 7.1 and Annexes 4 and 5). While dendritic features are prevailing in the less inclined areas in the middle part of the watershed, parallel features can primarily be found in the lower, V-shaped part of the catchment, where steep slopes are prevalent (see Annex 4) as well as in the headwater region above 2,900 m above sea level (see Annex 5). Particularly in the less inclined middle part of the catchment area with flat gradient, meandering was frequently detected. In general, particularly major stream branches were occasionally interrupted by small waterfalls and cascades.

Lalta river can be classified as a perennial stream. However, seasonal alternations correlating with the rainy and dry seasons occur (see fig. 55)[22]. According to local sources, a couple of small tributaries dry up towards the end of the Bega season (dry season between October and February, see fig. 16).

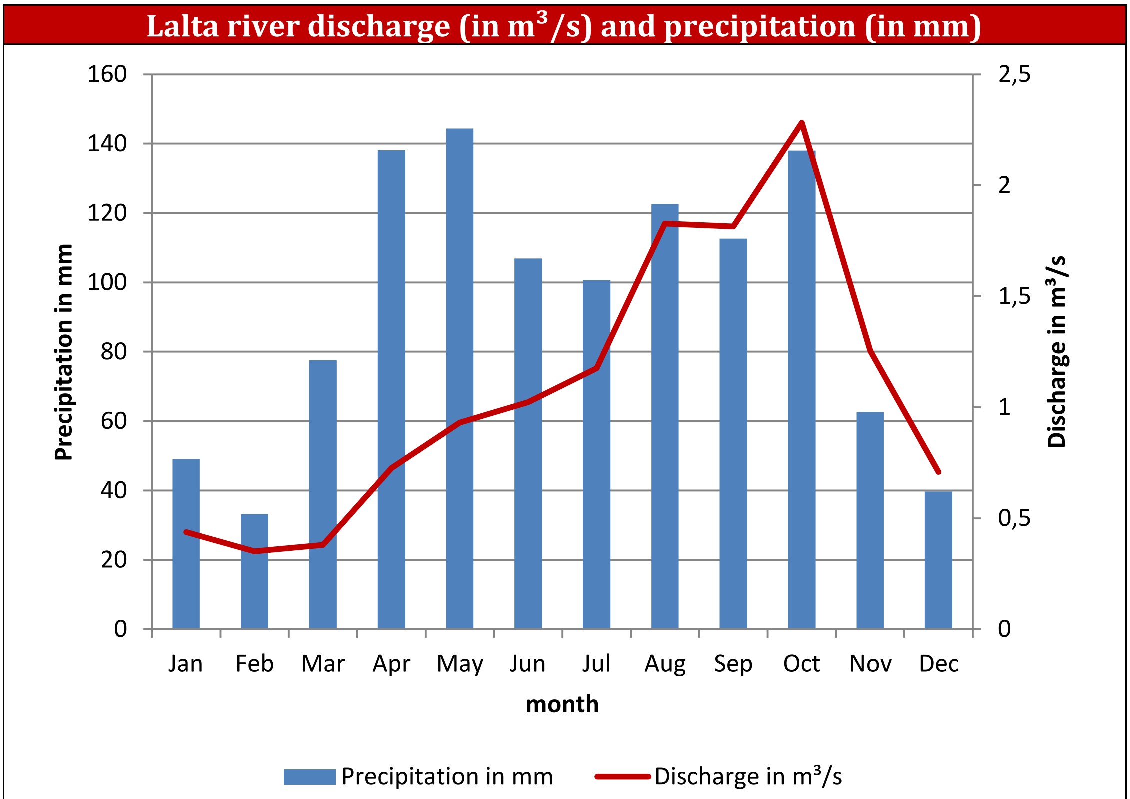

Fig. 55: Average monthly precipitation of the gauging stations Bensadaye, Arbegona and Hagere Selam (in mm) (survey period 2001 - 2007) and monthly discharge of Lalta river (in m^3/s) (survey period unknown). Source: Meder 2011 based on GIZ ECO staff information.

Agroecological zone The entire catchment is located in the agroecological zone "tepid to cool humid mid highlands", which is characterized by enset and cereal production. In terms of traditional agroecological zoning however, the lowest quarter of the catchment is characterized by the "Woina Dega" zone, while the upper ¾ of the catchment are located in the "Dega" zone (see fig. 27).

[22] When interpreting fig. 55, it should be kept in mind that neither long term rainfall data was available for the research site, nor the discharge survey period in known. The latter might explain alternations within the correlation (particularly March till June). The shown correlation between precipitation and rainfall is solely to be understood as a rough guideline.

Population According to GIZ ECO staff members, the current population of the catchment is approximately 5,000, not taking into account the full population of the Hagara Sodicha kebele since most of it is located south and thus downstream of the MHP powerhouse. Thus the current population density is approx. 160 people per km^2, which is less than Hula woreda's population density of 423.49 people/km^2 and significantly less than Aleto Wendo woreda's density of 684.89 people/km^2 (see footnote 15). Currently, the distribution of human settlement in the catchment area is comparably balanced, not taking into account agglomerations around market areas. However, a population growth around the powerhouse is likely to occur once the MHP is implemented. According to local sources, the fertility rate is high and although some families are leaving the area annually, population figures are rising in total.

Land use changes According to local sources, the catchment area was initially settled approx. 40 years ago (exact details varied by interviewee and might be inaccurate due to communication problems). Before that, the entire catchment was said to be widely covered with natural forest population. Once people started to settle in the area, most of the natural forest was cut down not only for fire wood and timber extraction, but also to transform the land for cultivation and pastoral purposes. Today, the catchment is intensively used by agriculture and pasture. In the downstream part of the catchment, mostly heterogeneous forest occurs in a mixed pattern with agricultural and pastoral use whereas in the upstream catchment forest primarily occurs in form of reforested, homogenous patches which are used for fire wood and timber extraction. For detailed information on today's land use, see chapters 7.2.1 and 7.2.2. Just like in the Gobecho catchment, land is traditionally split between all heirs within a family. Accordingly an increasing fragmentation of land ownership and thus land is likely to occur, especially since population figures are rising and polygamy is practiced in the area and 6 – 10 children per farmer are common. Due to increasing population figures, some households resettle to remaining forest areas and clear the trees for agricultural purposes (HASKAMP, KASSA 2010). As mentioned earlier, a population growth around the MHP is likely to occur, which also will affect the land use in areas adjacent to the thereby newly established agglomeration.

7.2.1 Hagara Sodicha downstream area

The downstream part of the Hagara Sodicha catchment has a total area of 1,482 ha (14.82 km^2) of which 1,152.2 ha (77.76%) were surveyed. Its elevation ranges from approx. 2,260m above sea level to approx. 2,700 m above sea level (see Annex 4).

7.2.1.1 Land use/land cover

The downstream part of the Hagara Sodicha catchment is characterized by a diversified and comparably balanced land use. 325.2 ha and thus 28.22% of the surveyed area are used for grazing, whereas permanent and seasonal crops are cultivated on 308 ha and 204.26 ha respectively, accounting for 26.73% and 17.73% of the total downstream area. Wetlands, which were detected on grazing areas, cover a total of 20.62 ha and thus account for 6.34% of the grazing land and 1.79% of the entire area. Forest and bush land cover 267.55 ha and 47.19 ha respectively and thus account for 23.22% and 4.1% of the total area surveyed (see fig. 56 and Annex 4).

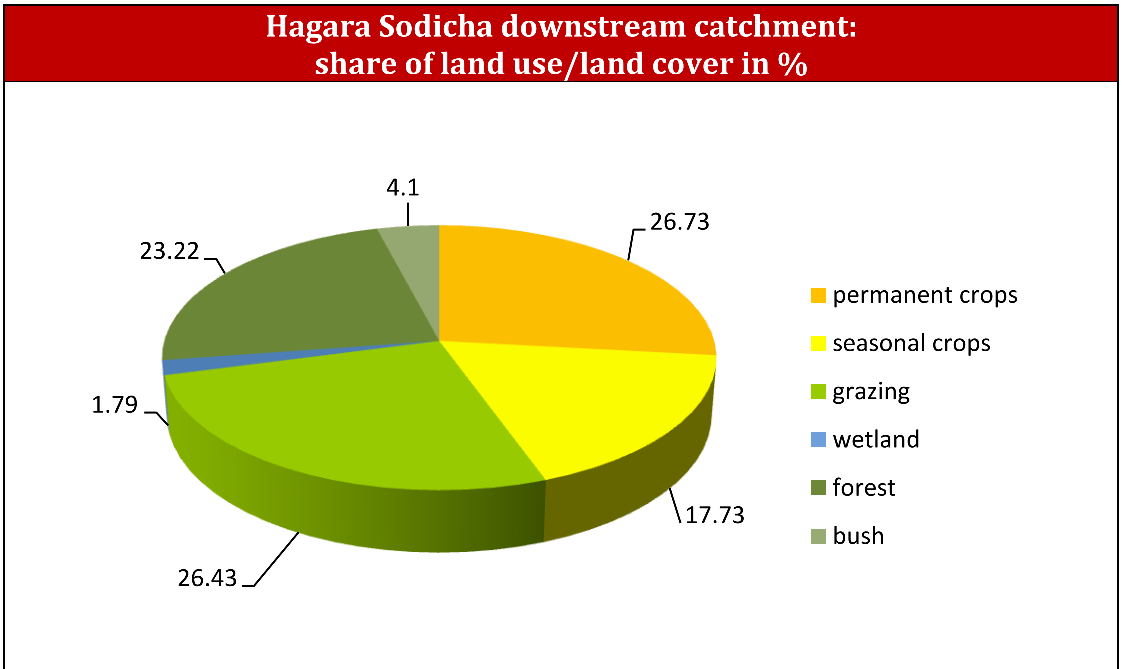

Fig. 56: Hagara Sodicha downstream catchment: share of land use/land cover in %. Data refers to the surveyed area. Source: Meder 2011.

The results of the checklist classification thus show a high occurrence of grazing, forest and permanent crop cultivation, a medium extent of seasonal crops and a low occurrence of bush land. The occurrence of wetlands can be classified as medium.

Agriculture The downstream part of the Hagara Sodicha catchment is intensively used by agriculture. The prevailing seasonal crops cultivated are barley and beans. The extent of the latter decreases with increasing altitude and is cultivated up to an altitude of 2,650 m above sea level. Furthermore, maize is grown up to an altitude of approx. 2,600 m above sea level, but to a much smaller extent than in the Gobecho downstream catchment. The prevailing permanent crop grown is enset. The land use pattern of the lower part of the downstream catchment, which is characterized by steep slopes, is highly diverse and seasonal as well as permanent cultivation plots are altering with grazing and forest plots (see fig. 57 and Annex 4). Plot sizes are rather small. Only on the upper parts of the slopes more coherent plots of enset cultivation were detected. The land use pattern of the less inclined upper part of the downstream catchment on the other hand, is more coherent. Plot sizes increase and cultivation of seasonal crops is primarily practiced on slopes whereas enset is grown on hilltops (see fig. 58 and Annex 4).

Hagara Sodicha downstream catchment: land use

Fig. 57: Hagara Sodicha downstream catchment: land use in the lower, steep part. Source: Meder 2011.

Fig. 58: Hagara Sodicha downstream catchment: land use in the upper, less inclined part. Source: Meder 2011.

Grazing Although grazing accounts for 28.22% of the downstream area surveyed, its occurrence and pattern differs between the upper and the lower part of the downstream sub-basin. Only few, comparatively small grazing plots were detected on the steep slopes of the lower part of the downstream catchment, which, as mentioned above, alter with agricultural and forest plots. Unlike in the upper downstream as well as the upstream part of the Hagara Sodicha basin and the entire Gobecho catchment, basically no grazing areas were found to be located along the water courses. In the upper part of the

downstream basin which is characterized by a less inclined topography, the quantity as well as the size of grazing plots increase and can primarily be found along water courses (see Annex 4). Collectively used grazing grounds do not exist in the entire Hagara Sodicha catchment. In general, each household is thus responsible for the land use and management practiced on the respective property (EGGER 2010).

Forest and bush With a total of more than 27% of the area surveyed, the downstream part of the Hagara Sodicha catchment is to a greater extent characterized by forest and bush occurrence than the upstream Hagara Sodicha basin and the entire Gobecho catchment. Particularly on steep slope parts, valley tops and along waterways, forest and bush land can be found. Especially in the lower part of the downstream catchment, where steep terrain is prevailing, forest patches of various sizes are integrated in the land use pattern (see fig. 57 and 59). Several extensive forest areas were detected along water ways primarily in the middle part of the downstream basin (see Annex 4). Furthermore, isolated perennial trees can be found throughout the downstream part of the catchment, which are often integrated in cultivation areas.

Forest in the Hagara Sodicha downstream catchment

Fig. 59: Mixed forest in the lower, steep part of the Hagara Sodicha downstream catchment. Source: Meder 2010.

Fig. 60: Bamboo occurrence in the foreground in the less inclined upper part of the Hagara Sodicha downstream catchment. Source: Meder 2010.

Towards the less inclined upper part of the downstream area, the quantity of bush occurrence decreases and forest patches primarily occur around springs or are located on the upper parts of slopes towards the hilltops (see fig. 60). Species in the lower part of the downstream catchment include bamboo and eucalyptus, but the latter are not as prevalent as in the other parts of the Hagara Sodicha and Gobecho catchments. A variety

of indigenous trees were spotted throughout this part of the catchment. Individual species could, however, not be identified due to translation problems. In the less inclined upper part of the downstream catchment, bamboo and eucalyptus characterize the forest occurrence and can primarily be found in either mixed or homogenous composition.
According to local sources, remaining forest areas, particularly those which are not used for timber and fire wood extraction, are increasingly deforested in order to reclaim land for agricultural purposes as population figures are steadily increasing.
Primarily in the upper part of the downstream basin, in-line planted eucalyptus and succulents can be found along waterways. Less frequent, they can also be found as fences around and/or between cultivation and grazing plots. These tree occurrences are not shown in Annex 4.

Springs, wetlands and waterways Wetlands occur on grazing areas along waterways or around springs in the upper half of the downstream catchment area, where the topography gets less inclined (see Annex 4). All wetlands detected are grass wetlands which often feature hydrophilic sedge grasses. No wetlands were detected in the lower part of the downstream area, presumably due to the steep topography which is prevalent in this part of the catchment. A total of 47 springs were detected in the downstream part of the Hagara Sodicha catchment. The average number of springs per km^2 is thus 4.08, which equals a high occurrence of springs. 27 springs were found to be surrounded by forest and 2 by bush cover. Hence 61.7% of springs have a vegetation buffer whereas 38.3% are located on grass covered areas. The prevailing species in spring areas was found to be bamboo, which either occurs in homogenous composition or interspersed with eucalyptus. Particularly in the lower part of the downstream catchment, species around springs also included indigenous trees and shrubs.

The total length of the stream net in the downstream part of the Hagara Sodicha catchment is 26,629.55 m of which 23,435 m and thus 88% were surveyed in the scope of this study. Vegetation buffer stripes were found to exist along a total of 11,320 m of water courses, which accounts for 48.3% (and thus a medium occurrence according to the checklist) of the surveyed total of water courses in the downstream part of the catchment. No vegetation buffers were found along 12,115 m (51.7% and thus a high occurrence according to the checklist[23]) of water courses (see Annex 4). Vegetation buffers in the lower part of the downstream basin are composed of a mix of a variety of indigenous species, mostly interspersed with bamboo and/or eucalyptus. In the upper part of the

[23] Although the checklist classifies the buffered and unbuffered waterways as medium and high, the actual numbers show little difference and thus a rather balanced distribution.

downstream catchment, the prevailing species along waterways primarily include bamboo and eucalyptus. In general, the land use pattern in the Hagara Sodicha catchment appears to be less orderly than the one of the Gobecho catchment.

7.2.1.2 Land use practices

All cultivation is rain fed, neither *irrigation* nor *drainage* measures are applied. No information on the application of *slash and burn practices* could be collected during field visits. According to a local farmer, a form of *rotational land use* is practiced in this part of the Hagara Sodicha catchment. However, detailed information on the practiced rotation could not be attained due to translation barriers.

7.2.1.3 Occurrence of degradation forms

7 *landslides* with the magnitudes 5 x 5 m, 5 x 10 m and 5 x 15 m (five times) were detected in the downstream part of the Hagara Sodicha catchment. With an average extent of 64.29 m^2 and an average quantity of 3.04 per 5 km^2 the ascertained degree of landslide degradation is high. 6 of the 7 landslides detected were found to be located in the lower, steep part of the downstream catchment. Only one is located in the less inclined upper part. 4 landslides are located in areas used for grazing whereas one was detected in enset cultivation, one in barley cultivation and one in bush land. Except for one, all landslides were detected in close proximity to water ways (see fig. 61 and 62 as well as Annex 4).

Degradation features in the Hagara Sodicha downstream catchment

Fig. 61: Landslide in the Hagara Sodicha downstream catchment. Source: Meder 2010.

Fig. 62: Landslide, riverbank erosion and cattle step in the Hagara Sodicha downstream catchment. Source: Meder 2010.

In the downstream part of the Hagara Sodicha catchment, 30 spots featuring *cattle step* were detected (see fig. 62). The average number of spots affected by cattle step is 2.6 per km^2. Cattle step was primarily found to occur on grazing land on hillsides (the average number of spots affected by cattle step per 1 km^2 grazing land is 9.2), isolated features were furthermore found in bush land (see Annex 4). Most areas featured a closed grass cover, however, 2 spots featuring bare soil were detected during the field survey.
In general the number of spots affected by cattle step ascends with increasing altitude. While only scattered small-sized plots were detected in the lower part of the downstream catchment, coherent and rather extensive areas were detected in the upper part of the downstream catchment. In the comparably low inclined middle part of the downstream catchment, particularly in the western part towards the market and northwestern part of the downstream catchment, no cattle step was detected, although grazing areas occur.

No *gully erosion* and *badland* features where detected in this part of the catchment area.

Two *river bank erosion* spots were detected in the downstream part of the catchment which equals an average quantity of 0.87 per 5 km^2 (see Annex 4 and fig. 62). The ascertained degree of river bank erosion is low.

No *sheet and splash erosion* was detected during the field visits.

7.2.1.4 Mitigation techniques

One example of *reforestation* was found in this part of the Hagara Sodicha catchment (see Annex 4). The project, which was implemented in 2010, included the planting of 1,000 indigenous seedlings. As of today, approximately half of the seedlings developed well according to GIZ ECO staff. Furthermore, the area is characterized by the application of *fencing of plots.* The cultivation and grazing plots are fenced by in-line planted eucalyptus trees, succulents of medium height or braided fences made of bamboo (see fig. 63).

Mitigation techniques in the Hagara Sodicha downstream catchment

Fig. 63: Fencing in the Hagara Sodicha downstream catchment. Source: Meder 2010.

Fig. 64: Agroforestry in the Hagara Sodicha downstream catchment. Source: Meder 2010.

However, the fencing is not applied as consistently and orderly as in the Gobecho catchment. In the scope of this study, it could neither be determined since when fencing is applied nor whether it is actually applied for mitigation purposes or solely to delimit property boundaries. 27 *springs* were found to be protected by forest and 2 by bush cover. It is unclear, however, whether the vegetation was preserved as a mitigation measure. For the prevailing vegetation composition, see chapter 7.2.1.1. In the lower part of the downstream catchment, *agroforestry* is practiced. As mentioned above, isolated indigenous trees can be found throughout the downstream part of the catchment, which are often integrated in cultivation areas (see fig. 64). However, it is unclear if the trees were not cut down for agroforestry purposes, as it is unknown whether the know-how of the measure exists among the famers in the area. According to local sources, farmers receive training on soil conservation measures by the woreda's rural development office. Interviews with local farmers showed that at least a partial understanding of the relation between (maladjusted) land uses and degradation exist. When asked about land slide events, they explained that the latter are primarily driven by deforestation. However, the understanding concerning the use and application of mitigation techniques is still limited (EGGER 2010).

7.2.2 Hagara Sodicha upstream area

The upstream part of the Hagara Sodicha catchment has a total area of 1650 ha (16.5 km^2) of which 1,451.89 ha (87.99%) were surveyed. Its elevation ranges from approx. 2,700 m above sea level to approx. 3,100 m above sea level (see Annex 5).

7.2.2.1 Land use/land cover

The upstream part of the Hagara Sodicha catchment is widely used for grazing. With 943.95 ha, accounting for 65.02% of the upstream basin, the latter is the prevailing land use in this part of the Hagara Sodicha catchment. Permanent and seasonal crop cultivation covers an area of 95.36 ha and 112.15 ha respectively and thus account for 6.57% and 7.72% of the entire area surveyed. Wetlands, which were exclusively detected on grazing areas, cover 7.57 ha and thus 0.8% of grazing land and 0.52% of the entire upstream basin. Forest covers 294.78 ha and thus 20.3% of the total area whereas bush land accounts for 5.65 ha and 0.39% (see fig. 65 and Annex 5).

Hagara Sodicha upstream catchment: share of land use/land cover in %

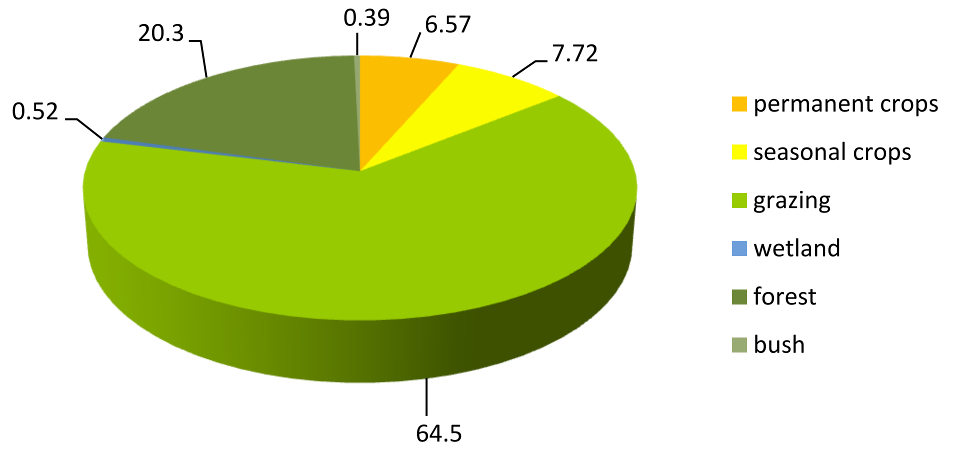

Fig. 65: Hagara Sodicha upstream catchment: share of land use/land cover in %. Data refers to the actually surveyed area. Source: Meder 2011.

The results of the checklist classification thus show a high occurrence of grazing and forest, whereas the cultivation of seasonal and permanent crops as well as bush land can be classified as low. Furthermore, the occurrence of wetlands can be classified as low.

Agriculture Barley is the only seasonal crop that was found to be cultivated in the upstream part of the Hagara Sodicha basin and is cultivated up to an altitude of 3,000 m above sea level. Cultivation plots can be found in upper slope areas and alternate with grazing land (see fig. 66). In general, the extent of barley cultivation decreases with increasing altitude. However, a rather large plot was detected to occur on comparatively flat terrain in the hilltop region towards the eastern catchment boundary. In the lower part of the upstream catchment, enset cultivation is practiced particularly on hilltops and alternates with the cultivation of cereal, forest and grazing plots. In the upper part of the upstream catchment, enset was found to be cultivated on a few spots at the catchment boundaries up to an altitude of 3,000m above sea level. In general, the quantity of enset production decreases with increasing altitude (see Annex 5).

Agriculture and grazing land in the Hagara Sodicha upstream catchment

Fig. 66: Agriculture (left and right background) and grazing land in the Hagara Sodicha upstream catchment. Source: Meder 2011.

Grazing accounts for 65.02% of the surveyed area of the upstream part of the basin and is thus the prevailing land use throughout this part of the Hagara Sodicha catchment. Particularly in areas above 2,900 m above sea level it covers extensive areas and is only sporadically interspersed by cultivation and forest batches (see fig. 66). According to local sources, agricultural cultivation was practiced in this part of the catchment right after the initial settlement of the area however, the land was not found to be fertile and was transformed into pastoral land instead. In the lower parts of the upstream basin, grazing primarily occurs along waterways and in areas on lower slopes. In this part of the upstream catchment it alternates with cultivation and forest plots (see Annex 5). In

various spots, a bias between fodder and non-fodder grass species was detected on grazing areas.

Forest and bush In the lower part of the upstream catchment, forest occurs in medium sized plots altering with other land uses. Mostly it can be found along waterways and around spring areas. Nonetheless, a fairly extensive forest area was found to occur towards the southeastern boundary of the catchment. The forest occurrences in the upper part of the upstream basin are restricted to spring areas and areas along water ways and are thus most often located in side valleys (see fig. 67 and Annex 5). Forest occurrences do not significantly decrease in size with increasing altitude. The prevailing forest type is bamboo, which mostly occurs in homogenous composition. Although considered indigenous, in this area bamboo is mostly reforested and grown for timber and fire wood extraction. Primarily in the lower part of the upstream basin, a mix of bamboo and eucalyptus was detected. Towards the western boundary of the upstream basin, remnants of natural forest were detected in steep terrain (see fig. 68). Due to the prevalent topographic conditions, no in situ inspection was possible. According to local sources, the detected area is one of few spots that have not been affected by the expansive deforestation which took place when the area was initially populated. Isolated and scattered indigenous trees were found in the entire upstream basin.

Forest occurrence in the Hagara Sodicha upstream catchment

Fig. 67: Bamboo occurrence along waterways in the Hagara Sodicha upstream catchment. Source: Meder 2011.

Fig. 68: Remnants of natural forest in the Hagara Sodicha upstream catchment. Source: Meder 2011.

Population of mixed indigenous trees and bushes can furthermore be found along waterways in the western part of the upstream catchment. However, in general, bush

land was rarely found to occur and is restricted to small areas along waterways and around springs. Throughout the upstream part of the catchment, in-line planted eucalyptus and succulents can be found along waterways. Less frequent, they can also be found as fences around and/or between cultivation and grazing plots.

Springs, wetlands and waterways Wetlands primarily occur in the lower part of the upstream catchment in less inclined areas and valley floors in particular. They can be found on grazing areas along waterways and around spring areas. All wetlands detected are grass wetlands and are characterized by hydrophilic sedge grasses. A total of 43 springs were surveyed in this part of the Hagara Sodicha catchment. The average number of springs per km^2 is thus 2.96, equaling a medium occurrence according to the checklist. 33 springs were found to be covered by forest and 4 by bush. Thus 86.05% of springs have a vegetation cover whereas 13.95% are located on grass covered areas (see Annex 5). The prevailing species in spring areas was found to be bamboo, which either occurs in homogenous composition or, particularly in the lower part of the upstream basin, interspersed with eucalyptus. Indigenous tree and shrub species were identified around springs in the western part of the upstream catchment.

The total length of the stream net in the upstream part of the Hagara Sodicha catchment is 24,329.96 m. The entire stream net and thus 100% was surveyed in this part of the catchment. Vegetation buffer stripes were found to exist along a total of 8,080 m of water courses, accounting for 33.21% of the surveyed total of water courses in the upstream part of the catchment and thus a medium occurrence according to the checklist. No vegetation buffers were found along 16,249.96 m (66.89%) of water courses, which equals a high occurrence according to the checklist (see Annex 5). Vegetation buffers in the lower part of the upstream basin are primarily composed bamboo and/or eucalyptus. In the western part of the upstream catchment, a mix of indigenous tree and shrub species were identified along waterways. In the upper part of the upstream catchment, the prevailing species along waterways primarily include bamboo and eucalyptus.

7.2.2.2 Land use practices

All cultivation is rain fed, neither *irrigation* nor *drainage* measures were found to be applied. No information on the application of *slash and burn practices* or *rotational land use practices* could be collected during field visits.

7.2.2.3 Degradation

2 *landslides* with the magnitudes 5 x 2 m and 10 x 10 m were detected in the upstream part of the Hagara Sodicha catchment. With an average extent of 55 m^2 and an average quantity of 0.69 per 5 km^2 the ascertained degree of landslide degradation is low. Both landslides are located on grazing land (see fig. 69). One landslide was found to be located

in close proximity to the river while the other was found to be located on the upper part of the slope close to the hilltop (see Annex 5).

52 areas with *cattle step* occurrence were detected in this part of the Hagara Sodicha catchment. The average number of spots affected by cattle step is 3.58 spots per km². Cattle step was found to occur primarily on grazing land but also on cultivation land on hillsides (the average number of spots affected by cattle step per 1 km² grazing land is 5.5) (see fig. 70 and Annex 5). Most areas featured a closed grass cover, however one spot featured bare soil. Cattle step occurrence is rather balanced and can be found throughout the valley slopes of the upstream basin. Commonly used cattle paths were found to be heavily affected by cattle step and featured gully-like appearance at some points. Almost all grazing areas feature cattle step and thus the degradation feature characterizes coherent and rather extensive areas. Almost no cattle step features were found on the rather low inclined grazing areas towards the eastern boundaries of the upstream basin. Cattle step was furthermore found to occur once each on and adjacent to wetland areas.

Landslide and cattle step in the Hagara Sodicha upstream catchment

Fig. 69: Landslide in the Hagara Sodicha upstream catchment. Source: Meder 2011.

Fig. 70: Cattle step in the Hagara Sodicha upstream catchment. Source: Meder 2011.

Except for the gully-like cattle paths, no *gully erosion* and *badland* features where detected in this part of the catchment area.

Two *river bank erosion* spots were detected in the upstream part of the catchment which equals an average quantity of 0.69 per 5 km². The ascertained degree of river bank erosion is low. The detected erosion spots were found to be located within an eucalyptus

forest of homogenous composition as well as on a grazing plot. Both spots were detected in the lower part of the downstream catchment (see Annex 5).

No *sheet and splash erosion* was detected during the field visits.

7.2.2.4 Mitigation techniques

The upstream area is characterized by the application of *fencing of plots.* Plots are fenced by cactuses of medium height, braided fences made of bamboo or in-line planted eucalyptus trees and occasionally other tree species. In the lower part of the upstream catchment the fencing is applied more consistently and orderly than in the downstream part of the catchment. Towards the headwater region, particularly on the wide grazing areas in the upstream catchment, the size of the fenced plots increases and fencing becomes less dense. However, in the scope of this study it could neither be determined since when fencing is applied nor whether it is actually applied for mitigation purposes or solely to delimit property boundaries. 33 *springs* were found to be protected by forest and 4 by bush cover. It is undetermined whether or not the vegetation was preserved as a mitigation measure. For the prevailing vegetation composition, see chapter 7.2.2.1. *Agroforestry* is also practiced in this part of the Hagara Sodicha catchment. As mentioned above, isolated perennial trees can be found in the upstream part of the catchment, which are occasionally integrated in cultivation areas. However, it is unclear whether the trees have not been cut down for agroforestry purposes, as it is unknown whether the know-how of the measure exists among the famers in the area. Other than that, no mitigation techniques were observed during the field survey.

8. Discussion of Results

The following discussion is drawn against the background of the relationship between land use, land use practices, degradation and sustainable use of MHP plants, in order to analyze whether the Gobecho as well as the Hagara Sodicha catchment are used sustainable in terms of MHP sustainability. As presented in the EA and WAP manual (Annex 1), the sustainable use of MHP plants will particularly be affected by alternation of discharge and sediment load of the river, which both result from various forms of inappropriate land use, land use practices and associated forms of erosion. Alternation of discharge will lead to insufficient and unsustainable electricity supply since, without a continuous discharge, the plant cannot be operated persistently. Sediment load of the river will wear out the turbine of the MHP and will thus decrease the durability of the plant's equipment. Results will be discussed structured by land use, associated land use practices and prevailing features of degradation. In general, all degradation causes, features and effects are closely interrelated and might be more comprehensive than presented. Thus not all interrelations will be examined in depth for each land uses as the latter are also closely interrelated. For more information see Annex 1.

8.1 Agricultural land

Both, the Gobecho and Hagara Sodicha catchment are intensively used for agricultural purposes, particularly in the downstream areas crop land covers extensive areas (see fig. 71 and chapters 7.1.1.1, 7.1.2.1, 7.2.1.1 and 7.2.2.1).

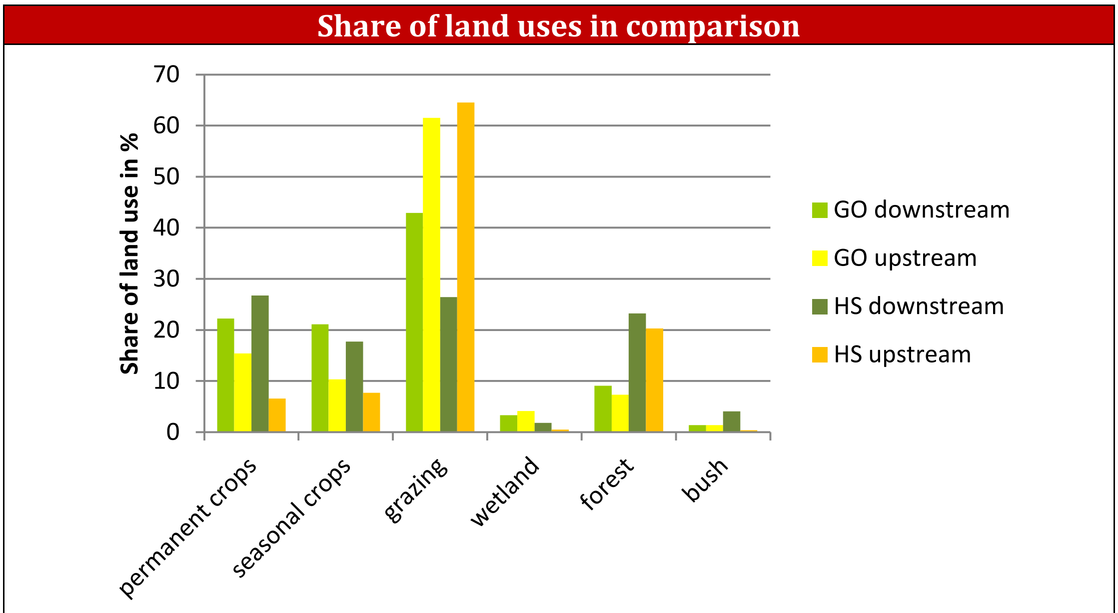

Fig. 71: Share of land uses in comparison between the up- and downstream parts of the Gobecho (GO) and Hagara Sodicha (HS) catchment. Source: Meder 2011.

In general, erosion from crop land is higher than from forest and grazing land use, particularly when practiced on hillsides. The cultivation of permanent crops such as enset is associated with a smaller erosion rate than the cultivation of seasonal crops such as maize and barley (LAL 1990). This is among others due to the fact that seasonal crops are cropped several times per year and thus bare soil, with higher erosion potential, is repeatedly exposed. However, it should be noted that different seasonal crops have varying erosion risks. Maize, which is the principal crop in the downstream part of the Gobecho catchment, has high soil erosion potential in comparison to other crops (see Annex 1). According to a study from the US, it was found to be more than 4 times higher than from sites where rotational cropping is practiced (LAL 1990).

Cropping land was found almost exclusively on hillsides and hilltops throughout both catchment areas. Due to land shortage associated with a high population growth and the practiced division of land between all heirs of a family, people increasingly move into less favorable places within the catchments, such as steep hillsides which have not been populated before due to their inaccessibility and/or incompatibility for farming (see chapters 7.1 and 7.2). Even in the steep areas of the downstream Hagara Sodicha catchment, settlements were found scattered all over the hillsides. This trend increases the overall erosion risk, since in general the latter increases with increasing inclination and thus upper slopes are at higher erosion risk than lower slopes (MORGAN 1999). Furthermore, the settlement in steep areas is most often associated with the cutting of forest areas in order to transform the land to make it applicable for cropping and/or pasture and to extract firewood and timber. In general, deforestation for any purpose increases soil erosion (LAL 1990). After deforestation takes place, neither a sufficient vegetation cover exists to protect the soil from sheet and splash erosion nor tree roots can stabilize the soil and thus bare soil with a high erosion risk is exposed. Moreover the soil lacks the improving impact of tree roots on soil structure which actually increases the soil's infiltration potential as well as water retention capacity (MORGAN 1999). Hence, deforestation and the associated exposure of bare soil leads to an increase of evaporation and the formation of air spaces (aridification) of the topsoil, which in turn reduces the water conductivity. On the one hand this leads to the creation of an evapotranspiration barrier and on the other hand it results in a decreasing infiltration rate and thus in increased surface runoff (MENSCHING 1990; see Annex 1). The relative erosion risk due to agriculture and associated deforestation can be illustrated by an example from Mexico. According to a study, the relative erosion from agriculture practiced on lower slopes was found to be 180 times higher than from forest areas, while agriculture practiced on upper slopes has an erosion potential 193 times higher. Erosion from bare soil was found to be even 576 times as high as from forest areas (LAL 1990).

An extreme form of degradation resulting from cropping and the preceding deforestation in steep terrain is landslides. Landslides in cropping land were detected in the downstream parts of the Hagara Sodicha as well as the Gobecho catchment on steep slopes (see chapters 7.1.1.3 and 7.2.1.3). Cropping as well as associated deforestation and hillside encroachment can have severe effects on the MHP's sustainable use, which can further be amplified by the cropping on extremely steep areas due to hillside encroachment. As explained above, the removal of forest cover for agricultural (and/or pastoral) purposes increases the erosion risk manifold. The decreased infiltration potential of the soil will lead to a decreased retention capacity and thus increases the surface runoff as well as the risk of flash floods during precipitation events and associated degradation features such as river bank erosion (see Annex 1). This especially applies for the beginning of the rainy season, when high rainfall amounts meet dry soil and will lead to an increased sediment load of rivers. The discharge of the rivers will be altered which might lead to a shortfall of the MHP plant's required minimum flow. Landslides will increase the sediment load in the water, caused not only by the initial debris from the event (landslides were repeatedly found adjacent to water ways) but also due to the increased soil erosion from the exposed bare soil (see Annex 1). The risk of landslides is high in the downstream parts of the Gobecho and the Hagara Sodicha catchment. Particularly the latter is characterized by steep slopes and many rather large events already took place in this part of the research area (see fig. 72 and chapter 7.2.1.3).

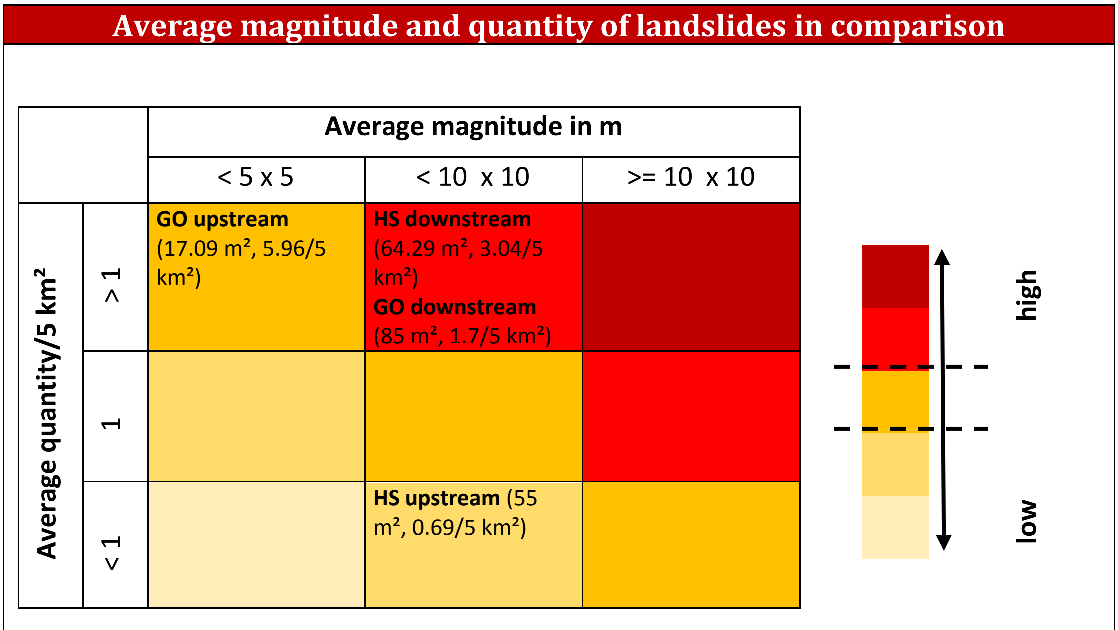

Fig. 72: Average magnitude and quantity of landslides in comparison between the up- and downstream parts of the Gobecho and Hagara Sodicha catchments according to the checklist (see Annex 1). Source: Meder 2011.

In case the magnitude of an event is big enough, the river might even be locked off completely, which could decrease or even stop the water flow and thus heavily affect the MHP use.

Positive findings in terms of sustainable land use, erosion control and thus MHP sustainability, were the cultivation pattern of season and permanent crops relative to the topography as well as the application of terracing, agroforestry and fencing of plots (see table 4 and chapters 7.1.1.4, 7.1.2.4, 7.2.1.4 and 7.2.2.4).

Table 4: Overview of applied mitigation techniques in comparison between the up- and downstream parts of the Gobecho and Hagara Sodicha catchment respectively. Source: Meder 2011.

	Gobecho downstream	Gobecho upstream	Hagara Sodicha downstream	Hagara Sodicha upstream
Terracing	applied			
Agroforestry	applied		applied	applied
Fencing	applied	applied	applied	applied
Reforestation		applied	applied	

The cultivation of permanent crops, enset in particular, is primarily practiced on hilltops throughout both research areas, while cultivation of seasonal crops, with some exceptions particularly in the upstream part of the Gobecho catchment, was primarily found to be practiced on lower slopes (see chapters 7.1.1.1, 7.1.2.1, 7.2.1.1 and 7.2.2.1). This spatial distribution decreases the erosion risk at least partially, since the cultivation of seasonal crops with a higher erosion risk than permanent crops is not located in the upper slopes which are more prone to erosion than the less inclined lower slopes.

Terracing was found to be applied on one spot located on the upper hillside in the downstream part of the Gobecho catchment (see chapter 7.1.1.4). The application of terraces decreases the erosion potential from steep slopes as the inclination as well as the slope length is decreased (MORGAN 1999). Hence surface runoff is reduced while the infiltration rate is increased.

Agroforestry was found to be applied in all parts of the catchments except for the upstream part of the Gobecho catchment (see chapters 7.1.1.4, 7.2.1.4 and 7.2.2.4). The integration of trees in cropping land not only increases the soil fertility due to the composting of organic material but also improves the soil structure and thus increases its infiltration potential as well as water retention capacity (MORGAN 1999). Hence, agroforestry has a positive effect on the sustainable use of the MHP since soil degradation is decreased and associated effects such as the alternation of discharge and an increased sediment load are diminished.

Fencing of plots was found to be applied around cropland in all four parts of the research sites (see chapters 7.1.1.4, 7.1.2.4, 7.2.1.4 and 7.2.2.4). Fencing helps to keep livestock off of cropland and thus to protect crops from damage due to cattle step and bite (see chapter 8.2). Furthermore fences can control runoff and serve as windbreakers and thus limit the wind erosion from cropland, particularly when bare soil is exposed (DESTA et al. 2005a; GEBREHIWOT 2004).

All of the erosion control measures described above contribute to the sustainable use of the MHP since erosion impacts such as increased sediment load and alternation of discharge are at least partially mitigated and/or decreased.

8.2 Grazing land

Grazing is the prevailing land use in the upstream regions of the catchments and cover extensive areas (see fig. 71 and chapters 7.1.1.1, 7.1.2.1, 7.2.1.1 and 7.2.2.1). In general, the erosion from well-managed pastures with controlled grazing and optimum stocking rates is less than from cropping land. However, accelerated erosion occurs from mismanaged and overstocked pastures which increase the erosion risk manifold (LAL 1990). Throughout both, the Gobecho and the Hagara Sodicha watersheds, extensive and severe cattle step occurrence was detected (see chapters 7.1.1.3, 7.1.2.3, 7.2.1.3 and 7.2.2.3). Furthermore, in both upstream parts of the catchments a bias between fodder and non-fodder plants were found to occur on grazing land. Both degradation features can be ascribed to overgrazing. Overgrazing occurs when the number of livestock on a unit of land is too high and the aforementioned management with controlled grazing and optimum stocking is not applied (see Annex 1). Resultant to this is the destruction of natural vegetation as well as soil compaction due to cattle step. The destruction of natural vegetation is not only favored due to the initial deforestation in order to transform former forest areas into grazing land, which took place throughout the last 40 years in both catchment areas, but also due to direct influence of cattle bite, cattle step and the selection of preferred fodder plants. In the long run, photosynthesis and thus biomass production as well as biodiversity will decrease. This will, in turn lead to a decrease of the area's carrying

capacity and might make the areas unusable for pasture (MENSCHING 1990; see Annex 1). Furthermore, the overall erosion risk will be increased due to more likely occurrence of an unclosed grass cover. Cattle step, which was primarily detected on steep slopes throughout both watersheds shows in form of small soil terraces along contour lines and a degraded vegetation cover, often interspersed with spots of bare soil. Due to the decrease of pore volume, the infiltration rate decreases, which can lead to an increased surface runoff (and thus increased erosion potential) (BALDENHOFER 2002). Furthermore, cattle step, which can be considered as an initial form of mass movement, might trigger landslides. In both catchment areas landslides were mostly found on grazing land and adjacent to cattle step occurrence. Along paths frequently used by livestock, gully-like erosion was detected (see chapters 7.1.2.3 and 7.2.2.3). Small gullies form along these paths which increase in size due to linear runoff through the latter (water follows the way of the lowest resistance) which is further increased by cattle step caused soil compaction and loss of vegetation cover and the associated decreased infiltration rate.

The effects of inappropriate grazing techniques and associated forms of degradation which were detected in both research areas might significantly decrease the MHP's sustainability. Due to the destruction of natural vegetation the topsoil experiences an increase of evaporation and hence the formation of air spaces (aridification), which in turn reduces the water conductivity. This leads, on the one hand to the creation of an evapotranspiration barrier and on the other hand it results in a decreasing infiltration rate and thus in increased surface runoff (MENSCHING 1990). Associated changes in soil moisture and groundwater thus not only decrease the retention capacity of the soil and alter the discharge but also increase the sediment load in the rivers which in turn negatively affects the sustainable use of the MHP. The latter will also be enhanced by the complete removal of grass cover as detected in various grazing spots in both catchments since bare soil has a higher erosion potential than grass land (LAL 1990). As mentioned earlier, cattle step will particularly decrease the pore volume of the soil, which does not only decrease the infiltration rate and thus alter the retention potential as well as the river discharge but will also lead to an increase of surface runoff, erosion and sediment load of rivers. Landslides will increase the sediment load in the water caused not only by the initial debris from the event (landslides were repeatedly found adjacent to water ways) but also due to the increased soil erosion from the exposed bare soil. It should be noted that landslides are not necessarily/exclusively linked to (over)grazing and were also found to occur in other land uses such as cropping (see chapter 8.1). Gullies might increase the sediment load in the rivers and can thus decrease the performance of the MHP in the long run.

In both watersheds grazing was often found to be practiced in and around spring and wetland areas as well as along water ways (7.1.1.1, 7.1.2.1, 7.2.1.1 and 7.2.2.1), which can

have negative effects on recharge of groundwater, water retention capacity of the soil and hence may lead to an alternation of discharge. Moreover cattle step may lead to instability of river banks and thus increased sediment load of the river. The particular effects of grazing in those areas on the MHP use will be further elaborated on in chapter 8.4.
The only measure found to be applied so far in terms of mitigation techniques to lessen the negative impact of grazing on the MHP is fencing. However, closed fences were only detected around cropland to protect the latter but not around grazing areas themselves.

8.3 Forest and bush land

Forest land has comparatively less erosion risk than arable or pastoral land (see chapter 8.1). As mentioned in chapters 7.1 and 7.2, both research areas used to be widely covered with natural forest before the area was settled in approx. 40 years ago. Both areas thus experienced extensive deforestation in order to create arable and grazing land and accordingly the catchment overall erosion potential has increased manifold in a rather short period of time. Particularly in the Gobecho catchment, forest and bush land cover only a small amount of land (see fig. 71). The altering and even destruction of natural vegetation associated with deforestation has an immense ecological impact on the hydrological condition of the catchments since forests do not only reduce evaporation and thus improve the annual retention capacity of the soil and help to provide a stable discharge rate, which is crucial for the sustainable use of the MHP, but they also help to decrease the risk of flash floods and thus severe erosion after heavy rains. Trees also stabilize the soil and thus not only decrease the sediment load of the river in general but also mitigate severe erosion events such as landslides. For further impacts of deforestation on MHP see chapter 8.1. Moreover, forests and vegetation cover in general act as buffers along water ways and around spring areas. If this buffer zone is removed, stream bank erosion might increase due to the destabilization of river banks which increases the sediment load. The impact of vegetation buffers will be further elaborated on in chapter 8.4.

Most of the forest areas detected in the watersheds are reforested and are of homogenous composition, mostly consisting of bamboo or eucalyptus trees (see chapter 7.1.1.1, 7.1.2.1, 7.2.1.1 and 7.2.2.1). All of these tree occurrences are used for timber and fire wood extraction which increases the soil erosion potential from forest areas since after cutting, bare soil might be exposed for some time before reforestation at the same plot takes place. As leaves are collected for fire purposes, the build-up of a humus layer for improved infiltration is often not provided. While bamboo is indigenous to Ethiopia, eucalyptus is an exotic species and has been introduced to the country approx. 100 years ago. Due to their fast growth and high water consumption, the extensive plantation of both species is ecologically controversial. Especially eucalyptus easily adapts to any soil and water

condition, and is characterized by fast growth, high survival, long roots and hard leafs which makes it economically very beneficial. However, it does not only take a lot of nutrients and water and is hence a high competition to companion plants decreases biodiversity, also soil erosion can occur as consequence of eucalyptus cultivation. FAO thus recommends that aforestation projects should avoid monocultures and the use of eucalypts in order to exclude large scale monocultures of eucalypt plantations from watersheds. The only way to include eucalyptus is to adopt it in agroforestry systems, but the proportion of each species should be planned out carefully (SUNGSUMARN 1993; see Annex 1).

The plantation of monocultures of bamboo and eucalyptus in particular thus might have negative impacts on the sustainable use of the MHP since soil hydrology might be altered and natural vegetation might get degraded. These impacts lead to a decrease of the infiltration rate, soil moisture and retention capacity and hence alter the discharge and increase the sediment load of rivers.

However, positive findings in terms of the sustainability of MHP were made as well during the field visits. Reforestation for re-vegetation and stabilizing purposes, e.g. in form of a re-vegetation of a landslide took place in the Gobecho as well as the Hagara Sodicha catchment (see table 4 and chapters 7.1.2.4 and 7.2.1.4). Reforested areas (with the exception of the above mentioned plantations for timber and fire wood extraction) contribute to the general erosion control in terms of reduction of sediment load of the rivers and alternation of discharge (see chapter 8.1) and thus contribute to a sustainable use of the MHP.

Furthermore it should be noted that the implementation of the MHP plant and the associated electricity supply might decrease the fuel wood demand and thus contribute to a decreased deforestation rate. However, MHP implementation is also associated with a population growth around the powerhouse and thus the pressure on resources and the degradation risk might increase after all.

It should be noted, that although the plantation of bamboo and eucalyptus in particular have negative effects on the hydrological condition of the watershed and thus on the MHP, it is at the same time economically beneficial for the local famers. Hence its proposed abandoning from the watersheds might pose a point of conflict between different stakeholders in the catchments (see Annex 1).

8.4 Springs, waterways and wetlands

Springs are sensitive areas that react to disturbances easily. They do not only guarantee the discharge in dry season, but also have a great retention capacity during and after rains. Protection of springs and wetlands is thus crucial for the sustainable use of the MHP

projects since without a stable discharge, continuous electricity generation and supply cannot be provided. Protection measures of springs include fencing (to protect the areas from cattle step and thus soil compaction), protection of natural vegetation around the springs as well as protection of a natural humus layer (in order to sustain sufficient infiltration and thus groundwater recharge). Furthermore fencing can help to improve the water quality since pollution due to agricultural and pastoral use can be prevented (HELVETAS 2005). The protection of a vegetation buffer is not only beneficial in spring areas but also along waterways. A vegetation buffer typically consists of a band of vegetation around a spring or wetland or along a water body, preferably natural habitat and performs a variety of functions which can improve the environmental condition of a watershed. Functions include sediment removal and erosion control, runoff reduction through infiltration, decease of evaporation, reduction of human and livestock impacts by limiting easy access as well as barrier to invasion of exotic species (GALE undated; see Annex 1). Less than 50% of springs and only 23.68% and 5.72% of waterways in the Gobecho down- and upstream catchment respectively were found to be protected by a vegetation buffer (see fig. 73 and chapters 7.1.1.1 and 7.1.2.1). Only very occasionally springs were detected to be protected by braided bamboo fences.

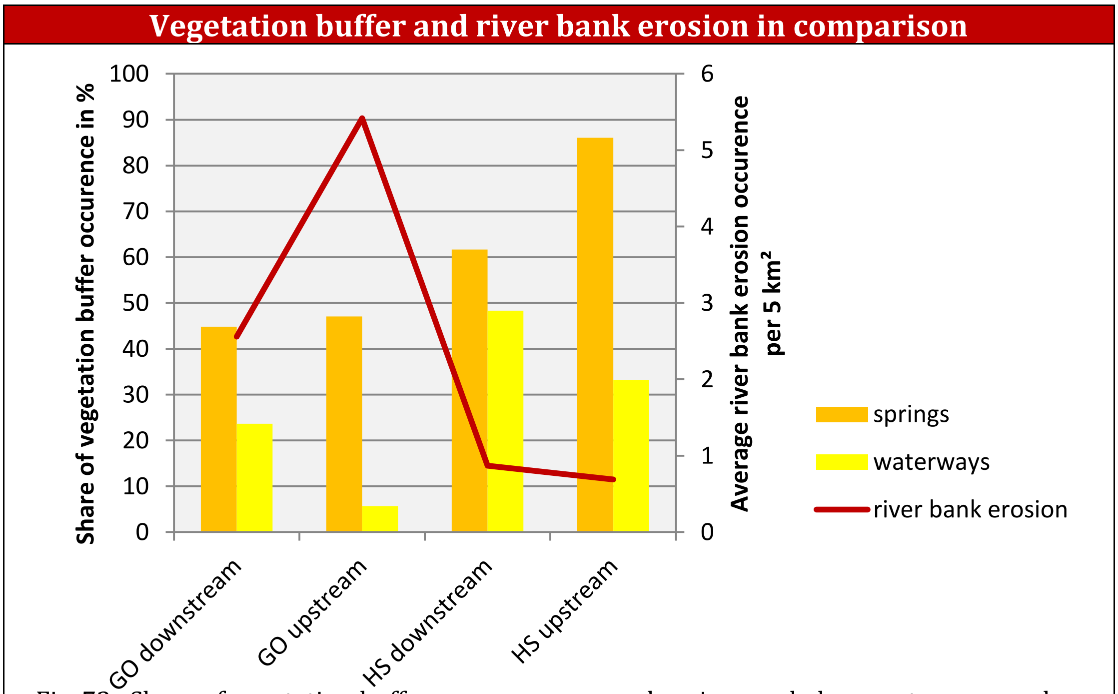

Fig. 73: Share of vegetation buffer occurrence around springs and along waterways and average occurrence of river bank erosion in comparison between the up- and downstream parts of the Gobecho (GO) and Hagara Sodicha (HS) catchment. Source: Meder 2011.

61.7% and 86.05% of springs and 48.3% and 33.21% of waterways are protected by a vegetation cover in the down- and upstream part of the Hagara Sodicha catchment

respectively, which might be due to the training farmers receive (see fig. 73 and chapters 7.2.1.1 and 7.2.2.1). However, in both catchments, buffers were found to primarily consist of homogenous, afforested fast growing bamboo or eucalyptus trees or a mix of both. Remnants of natural vegetation in spring areas and along waterways were only detected in a few spots, mostly interspersed with individual bamboo or eucalyptus trees. Although buffers in general are beneficial, their actual effects, and in the context of this study benefit for the sustainable use of the MHP, depend on their composition. The prevailing homogenous bamboo and eucalyptus buffers found in the two research areas not only consume more water than heterogeneous vegetation but also prevent evaporation less effectively (EGGER 2010) (see chapter 8.3 and Annex 1). Thus their effect on the MHP is ambiguous: on the one hand they have positive effects such as the stabilization of the soil and the prevention of livestock encroachment in spring/waterway areas but on the other hand they reduce the soil's retention capacity and thus negatively affect a stable discharge rate. Furthermore, the aforementioned bamboo and eucalyptus forests are used for timber and firewood extraction and can thus not be considered permanent buffers. However, as mentioned earlier, it is crucial to preserve a natural humus layer around the springs in order to provide for a slow infiltration of surface water to recharge the groundwater and to prevent the spring from running dry (see chapter 8.3 and Annex 1). The formation of a humus layer is not only restricted to vegetated areas but can also be affected by the human collection of leaves in order to use it for fuel, which is often practiced in these forest areas.

A lack of vegetation buffer not only negatively affects the hydrological condition of the watershed and thus the MHP in terms of retention capacity and provision of a stable discharge rate but can also have direct physical impacts on the river banks in form of river bank erosion. River bank erosion is not only triggered by the lack of a stabilizing vegetation buffer along waterways but is also closely linked to increased runoff and associated alternation of river discharge. When land use changes, such as clearing land for agriculture, occur in a watershed, runoff increases and thus the stream channel adjusts to accommodate the additional flow, causing stream bed erosion. Moreover, pastoral use along water ways reinforced this form of erosion (SURRY SOIL AND WATER CONSERVATION DISTRICT et al. undated; see Annex 1). While stream bank erosion was detected in all four parts of the two research sites, the highest occurrence was found in the upper part of the Gobecho catchment, which at the same time has the lowest occurrence of vegetation buffers along water ways (5% contrary to 23% in the downstream Gobecho catchment and 50% and 33% in the Hagara Sodicha downstream and upstream catchment respectively, see fig. 73 and chapters 7.1.1.3, 7.1.2.3, 7.2.1.3 and 7.2.2.3). River bank erosion significantly increases the sediment load of the river, which not only results in the loss of fertile cropland but also negatively affects the sustainable use of the MPH plant.

Also in this context, the positive and negative effects of bamboo and eucalyptus cultivation should be taken into account (see chapter 8.3 and Annex 1).

Wetlands, which can be found throughout the two catchments, are of great importance for the sustainable use of the MHP (see fig. 71). These waterlogged areas are characterized by a high water retention capacity and are hence crucial for a stable annual discharge, since even in the dry period they provide water for the streams and regulate the water flow. Vice versa, as they have a great potential to store water during precipitation events, wetland areas help to decrease the initial runoff and thus decrease the risk of flash floods and associated forms of degradation such as river bank erosion. However, in both catchments wetlands were frequently found to be used inadequately. Almost all detected wetlands overlap with grazing areas and have thus to be considered as a result of human action: not only have they most likely been affected by deforestation and hence an alternation of natural vegetation and natural vegetation buffer removal respectively, but furthermore they are affected by the impacts of grazing such as cattle step. Both interferences in the natural condition of the wetlands decrease their potential to recharge and store water and thus to regulate the annual water flow. Thus they increase the chance of the river drying out during the dry season which, in a worst case scenario, might lead to an interruption of the MHP generated electricity supply during this season.
Furthermore, drainage of wetlands was found to be applied in the Gobecho catchment in order to improve the site conditions for agricultural land use as drier soil conditions provide for positive effects in agricultural terms such as higher and more diversified crop production, better workability of the land and earlier planting dates and thus an overall yield increase (OOSTERBAAN 1994) (see chapters 7.1.1.2 and 7.1.2.2). However, in terms of the sustainable use of the MHP, negative effects of drainage are predominating since drainage alters the natural discharge of water from the wetlands and thus decreases the available amount of water in dry seasons. Hence, drainage increases the risk of the rivers drying out during dry season which will, just like the inadequate use of wetland areas, affect the permanent use of the MHP. It should be noted, that drainage provides both, positive (in terms of agricultural production) and negative (in terms of MHP) effects for the catchments' population. Drainage can thus be stated as a conflict of interests between different stakeholders in the watershed. Its application should thus be discussed carefully, taking into account short as well as long-term positive and negative effects (see chapter 8.3 and Annex 1).

8.5 Identified Problems

It should be noted that land use, land use practices, degradation and hence the sustainability of the MHP plants are closely interrelated. As shown in the discussion, land use specific erosion rates as described in the manual (see Annex 1) can be modified by

appropriate and inappropriate land use practices and mitigation techniques. Monocausal correlations between land use and erosion should thus always be questioned critically while taking into account applied land use techniques and their positive or negative impacts on the environment. Summarizing the findings and the discussion, all four parts of the Gobecho and Hagara Sodicha catchment feature both positive, but primarily negative land use practices. Since agriculture, pasture and forestry is the economic basis for most of the people living in the two catchments, environmental protection needs to be included in the land use in form of appropriate land use and mitigation techniques, as re-naturalization is not an option. The EA and WAP manual recommends to establish a list of major identified problems found in the watersheds, taking into account the findings (including the checklist classification) as well as the discussion. Since the list includes features and causes of degradation (including inappropriate land use techniques), doubling might occur. It should solely be considered as a guideline and not as complete. A list of identified problems is shown in table 5.

Table 5: List of identified problems (including features and causes of degradation) in the upstream and downstream parts of the Gobecho and Hagara Sodicha catchments. Italic font in brackets indicates the respective degree of degradation according to the checklist classification. Where no degree of degradation is indicated, it was not possible to analyze the respective data according to the checklist. Source: Meder 2011.

	Gobecho downstream	**Gobecho upstream**	**Hagara Sodicha downstream**	**Hagara Sodicha upstream**
Features of degradation	landslides (*high*)	cattle step	landslides (*high*)	cattle step
	river bank erosion (*high*)	river bank erosion (*high*)	cattle step	landslides (*low*)
	cattle step	landslides (*medium*)	river bank erosion (*low*)	river bank erosion (*low*)
Causes of degradation	hillside encroachment	overgrazing	hillside encroachment	overgrazing
	deforestation/lack of vegetation buffers	deforestation/lack of vegetation buffers	overgrazing	hillside encroachment
	overgrazing	hillside encroachment	deforestation	deforestation/ lack of vegetation buffer

9. Recommendations

The discussion of results shows that land use, land use practices, erosion and the sustainability of the MHP are closely interrelated. Both catchments feature positive and negative land use practices in terms of MHP sustainability. However, negative findings are prevailing. In order to improve the overall ecological condition of the two catchments and to decrease erosion and thus enhance the MHP plants' sustainability, recommendations of appropriate land use practices and mitigation techniques are given. In general, the application of appropriate land use practices does not only contribute to the sustainability of the MHP use but also improve the general environmental condition of the catchment which will have further long-term socio-economic benefits, such as increased crop yields, for the population. Recommendations will not only be given for the causes and features of degradation listed in table 5 but will also include general recommendations on land use practices in order to take into account the comprehensive correlation between land degradation and land use techniques. Recommended mitigation techniques will hence not only focus on the degradation *features* visible in the landscape such as cattle step and landslides but will try to diminish the *causes*[24] of degradation features in order to mitigate them in the long run and thus to contribute to the sustainability of the land use as well as the MHP plants. Although the four catchment parts feature different extension of the individual land uses, land use techniques and associated causes and features of degradation, similar (basic) recommendations apply to all four parts of the catchments. The latter will thus be given according to land use and not according to catchment, while taking into account the prevailing agroecological zone. However, indications which technique is particularly recommendable in what part of the two catchments will be given at the respective part of the text and are summarized in tables 6 and 7 at the end of this chapter.

The recommended practices and techniques are primarily based on the SLM publications DESTA et al. 2005a and DESTA et al. 2005b (manual Annexes 3 and 4). Moreover it should be noted that this chapter partly draws upon the manual text.

[24] As shown in Annex 1, causes of degradation can be manifold. In the scope of this paper, recommendations will only include direct causes such as deforestation and overgrazing since they are likely to be applicable in the context of the respective MHP projects. It should be noted that socio-economic as well as political causes such as population growth can heavily contribute to land degradation but exceed projects' area of influence. However, if well adapted land use is practiced the negative impact of the latter can be significantly decreased.

9.1 Agricultural land

There are various ways to decrease the erosion potential of agriculturally used land. The following recommendations are solely pointing out possible measures and do not claim to be complete and/or exclusive. Particularly in terms of soil fertility management and biological soil conservation there are various measures that are recommendable to contribute to decreased erosion, regulated discharge and thus to the MHP sustainability. In order to improve the water storage within the soil profile, reduce surface runoff and thus erosion, compost making is recommended throughout both catchment areas. For more information see manual's Annex 3, p. 127 and 128. Furthermore, mulching and crop residue management is highly recommended to be applied. Mulching is the covering of soil with crop residues such as straws or standing stubble which protects the soil from raindrops, decreases runoff velocity and thus drastically reduces sheet and splash erosion. Although no sheet and splash erosion was detected in either of the catchments, the measures are still recommended since they furthermore increases soil infiltration and permeability, prevents the formation of hard crusts (see Annex 1) and thus contributes to a general improvement of soil fertility. For more detailed information see manual's Annex 3, p. 131.

Although fencing and vegetative fencing was found to be applied in all four parts of the catchments it is recommended to apply it even more comprehensively, for example as a "grid system". Especially when implemented over large areas and along contour lines, fencing can decrease runoff and thus erosion. As fences also act as wind breakers, they reduce evapotranspiration and thus the risk of soil aridification. For more details see chapter 8.1 and manual's Annex 3, p. 135. However, fences made of in-line planted eucalyptus trees should be avoided, particularly along waterways (see chapter 8.3). In terms of cultivation practices, the application of crop rotation and strip cropping is recommended. Crop rotation is the growing of different crops at the same piece of land one after another. The practice improves soil fertility and structure as well as vegetation cover and thus reduces runoff and soil loss, which is beneficial in terms of MHP sustainability. Strip cropping, which includes the cultivation of two or more crops alternately along the contour, can reduce erosion among other benefits. Although strip cropping needs to be implemented in combination with additional conservation structures such as bench terraces above 5% slopes, its application is particularly recommended in maize cultivation and thus in the downstream part of the Gobecho catchment. For more information on the recommended land use techniques, see manual's Annex 3, p. 139 and 140.

As agroforestry is at least partially practiced in the entire Hagara Sodicha catchment as well as the downstream part of the Gobecho catchment, it is recommended to further intensify its application and to extend it to the upstream part of the Gobecho catchment. Particularly multi-storey gardening is recommended, which includes the planting of mixed

crops, shrubs and trees of different height and uses in order to increase soil fertility and decrease soil erosion. There are various other agroforestry measures that can be applied. A technique recommended for the two catchments is area closure, which combines techniques such as strip cropping and improved pits in order to close an area before the rainy season as to decrease soil erosion. For more information see manual's Annex 3, p. 143, 144 and 152.
In terms of flood control, the application of stone paved waterways is recommended in order to receive/accommodate runoff from graded terraces/bunds (see below). The waterways lead the runoff to rivers safely without creating erosion. For more information see manual's Annex 3, p. 83. In combination with the waterways, the application of graded soil bunds is recommended on slopes up to 30% gradient. The bunds reduce/stop the velocity of runoff and thus decrease soil erosion. While the bunds allow excess runoff to drain into adjoining natural or artificial waterways, stored water within the ties can infiltrate into the soil and thus increase soil moisture, contributing to a stable discharge rate of rivers. The measure can be gradually developed into bench terraces through carful maintenance. For more information see manual's Annex 3, p.86 and 117.

9.2 Grazing land

All four parts of the catchments are more or less heavily affected by cattle step. Nonetheless pasture is one of the main income sources of the local population and can thus not be prohibited or strongly constrained. Since the situation might get even worse since an increase of livestock is likely to occur as population figures are rising, it is strongly recommended to introduce a grazing plan in order to lessen the pressure on vegetation cover and soil. The grazing plan should be planned out carefully, taking into consideration that not more than 40 – 50% of fodder plants' annual production should be grazed in order to provide a vegetation cover of at least 70% at any time (MORGAN 1999). Furthermore, the installation of more coherent fencing is recommended in order to prevent livestock interference in not only heavily degraded areas but also in wetland and spring areas as well as areas adjacent to waterways (see chapters 9.1 and 9.4). In order to decrease the runoff from particularly degraded grazing land, the application of stone paved waterways as well as graded soil bunds is also recommended on grazing land (see chapter 9.1).

9.3 Forest and bush land

Natural forest remnants, particularly in the upstream part of the Hagara Sodicha catchment, are recommended to be preserved. Reforestation is recommended particularly on steep hillsides, around spring and wetland areas as well as along water ways (see chapter 9.4) and areas affected by landslides and cattle step. It should be noted, that not all species are suitable for reforestation and should thus be selected carefully by taking into

consideration the environmental condition (Morgan 1999). A list of species suitable for the application in the agroecological zone Dega, which is prevailing in both catchment areas and their specific use, can be found in manual's Annex 4, p.53. Reforestation should always include a mix of various species with different physiognomy in order to provide for sufficient light and thus for the establishment of a multiple layer vegetation cover which will prevent soil erosion more effectively than a homogenous canopy. Moreover, reforested patches in the respective areas should not be used for timber and firewood extraction. Since the latter is part of the economic base of the local population and it is thus hard to prohibit deforestation for timber and firewood extraction, regulations of areas, amount and frequency for cutting should be established in order to minimize the environmental impact. It is recommended to prevent extensive deforestation in order to avoid bare soil from being exposed at any time. It is furthermore recommended to prohibit the collection of leaves in forest areas, including both natural and planted forest patches, in order to enhance the generation of a humus layer. Although the electricity supply might decrease the fire wood extraction as well as the collection of leaves anyway, it is moreover recommended to provide further strategies to cope with the decreased fire wood supply. In order to avoid the substitution of fuel wood and leaves by dung, which would have negative impacts on soil fertility since it cannot be used as fertilizer anymore, it is recommended to decrease the overall fuel wood demand for example by the distribution of improved cooking stoves with higher energy efficiency (see chapter 3). Although eucalyptus planting is economically beneficial and practiced throughout Ethiopia, in terms of MHP sustainability it is recommended neither for fencing and timber nor for stabilization purposes due to its ecological effects (see chapter 8.3 and Annex 1). However, even the SLM publications (manual's Annexes 3 and 4) recommend eucalyptus planting. If planting eucalyptus anyway, its benefits and negative impacts on the ecological condition of the catchments should be carefully weighed at any time.

9.4 Springs, waterways and wetlands

Wetlands and springs are crucial for the retention capacity of the soil as well as a continuous discharge and thus need protection in order to provide sustainability of the MHP plants. It is recommended to protect wetlands and springs by fencing and to preserve/reinstall a natural/indigenous vegetation cover (see chapters 9.2 and 9.3). No livestock should be kept in these areas, to prevent damage due to cattle step and cattle bite. It is recommended not to apply draining of wetland areas and to preserve/install sufficient vegetation buffers along water ways, preferably consistent of a mixed composition of indigenous plants to prevent river bed erosion, increased evaporation as well as intrusion by livestock. Re-vegetation of wetlands, springs and waterways as well as the abandoning of draining is particularly recommended for the entire Gobecho catchment. Both buffers around spring and wetland areas as well as along waterways

should not be used for timber and or firewood extraction in order to provide sustainable protection.

9.5 Training

Although some mitigation techniques such as fencing were found to be applied in both catchments, it is recommended to provide further training to the local population, particularly since the overall understanding of mitigation techniques is still missing according to local sources. Training should not only include the solely technical aspects of the proposed mitigation techniques but should furthermore make people aware of the correlation between land use, land use practices, erosion potential and MHP as well as environmental sustainability by taking into account the overall and long term benefit of the recommended techniques and practices. This is particularly crucial since the MHP projects will primarily supply electricity to population living close to the powerhouse and thus in the downstream part of the catchment. Nonetheless, many mitigation and intervention techniques are recommended to be implemented in the upstream parts of the catchments as the latter are most important for the retention capacity of the soil and thus for a stable discharge rate, which in turn is crucial for a sustainable use of the MHP. Hence the upstream population needs to understand the long term benefit they will gain from the implementation of various mitigation and intervention techniques, such as higher yields and income generation due to improved soils, although they will not directly benefit from the electricity supply (see Annex 1).

Each farmer is responsible for his own land and thus for the implementation of mitigation techniques. Due to the practiced subdivision of land between all heirs of a family and the population growth, an increasing number of farmers need to be trained and made aware of the overall benefit of the application of appropriate land use techniques. However, since some recommended measures are rather labor and cost intensive, a sense of collectiveness needs to be generated in order the implement the latter collectively (see Annex 1).

9.6 Monitoring

It is recommended to monitor the impact of the applied mitigation techniques and appropriate land use techniques by measuring the river's sediment load as well as its discharge. In the scope of this study, only short term discharge and climate data on the two research sites was available. In order to establish a more significant baseline for future monitoring results it is thus recommended to measure the precipitation as well as the discharge once per day (e. g. at the intake) as soon as possible. In terms of sediment load it is recommended to remove and measure the sediment that builds up in front of the penstock every two to three months (but either way always in the same time interval). Data should be analyzed against the backdrop of the assumption that a reduced sediment

load of rivers as well as a continuous discharge indicate an overall improvement of the catchments' environmental state, thus less erosion features and effects and an increased sustainability of the MHP plants.

However, it should be noted, that the recommended monitoring techniques are rather unparticular (discharge is for example highly dependent on precipitation, which is in turn highly variable from year to year (see fig. 15)) and should only be considered a rough guideline. Hence, it is recommended to repeat the entire environment assessment process every year in order to monitor the overall change in the catchment and to learn more about what measures were actually implemented successfully (see Annex 1). In general, all monitoring data should be repeatedly collected in the same season/time of the year in order to attain comparable data (example: towards the end of the dry "Bega" season small tributaries and springs might dry up). In this context it should be noted that the field data for the study presented in this study was collected between October and mid-January and thus primarily in the first half of the dry "Bega" season.

9.7 Overview: Recommendations

The recommended mitigation techniques (see table 6 and 7) will help to decrease the environmental degradation in the catchments, thus decrease the risk of an alternation of discharge and decrease the sediment load of rivers in the long run which in turn will enhance the MHP plants' sustainability.

Table 6: Overview of recommended mitigation techniques according to the list of identified problems (see table 5) and catchment. Identified problems are written in normal font whereas recommended techniques are written in bold font. Since the table shows recommendations for both, features and causes of degradation, doubling might occur. Source: Meder 2011.

	Gobecho downstream	Gobecho upstream	Hagara Sodicha downstream	Hagara Sodicha upstream
Features of degradation and recommended mitigation techniques	landslides: **reforestation**	cattle step: **grazing plan, fencing**	landslides: **reforestation**	cattle step: **grazing plan, fencing**
	river bank erosion: **reforestation**	river bank erosion: **reforestation**	cattle step: **grazing plan, fencing**	landslides: **reforestation**
	cattle step: **grazing plan, fencing**	landslides: **reforestation**	river bank erosion: **reforestation**	river bank erosion: **reforestation**
Causes of degradation and recommended mitigation techniques	hillside encroachment: **graded soil bunds, bench terraces**	overgrazing: **grazing plan fencing**	hillside encroachment: **graded soil bunds, bench terraces**	overgrazing: **grazing plan, fencing**
	deforestation/lack of vegetation buffers: **natural forest preservation, reforestation, limited/regulated timber and firewood extraction**	deforestation/lack of vegetation buffers: **natural forest preservation, reforestation, limited/ regulated timber and firewood extraction**	overgrazing: **grazing plan, fencing**	hillside encroachment: **graded soil bunds, bench terraces**
	overgrazing: **grazing plan fencing**	hillside encroachment: **graded soil bunds bench terraces**	deforestation: **natural forest preservation, reforestation, limited/ regulated timber and firewood extraction**	deforestation/ lack of vegetation buffer: **natural forest preservation, reforestation, limited/ regulated timber and firewood extraction**

Table 7: Overview of further recommended mitigation techniques according to land use and general recommendations which apply to all four parts of the catchments. Source: Meder 2011.

	Both catchments
Generally recommended mitigation techniques	**Agricultural land:**
	compost making **mulching and crop residue management** **agroforestry (multi-storey gardening, area closure)** (extent it to Gobecho upstream catchment) **fencing and vegetative fencing** **crop rotation and strip cropping** (particularly Gobecho downstream catchment) **stone paved waterways**
	Grazing land:
	stone paved waterways **graded soil bunds**
	Forest and bush land:
	no eucalyptus plantation
	Springs, waterways and wetlands:
	no application of draining of wetlands **fencing** **preservation/ reinstallation of vegetation buffers**
General recommen -dations	**training** **monitoring**

If applied appropriately and consistently, adapted land use practices can not only decrease the currently existing erosion potential in the watersheds but will also mitigate further erosion due to future developments such as the approximated population growth around the power house due to the MHP installation. It should be noted that the given recommendations should not be considered complete and/or exclusive, meaning that other combinations of measures might also improve the watersheds environmental condition and thus contribute to the sustainable use of the MHP. Furthermore, the feasibility in terms of financial and labor resources as well as the actual benefit needs further investigation as well as coordination with the respective MHP project.

10. Limitations, study recommendations and conclusion

The study recommendations are closely related to the limitations of the on hand study. As indicated throughout this paper, not all data could be collected as described in the EA and WAP manual (Annex 1) primarily due to time, access and translation constraints. This particularly shows in the fact that only a certain percentage of the two catchment areas was actually surveyed as well as not all data was surveyed as described in the EA and WAP manual (example: cattle step, see chapter 7.1.1.3). Thus it is recommended to not only survey the entire catchment area if possible but also to survey data more according to the manual in future studies as to achieve results as accurately as possible. Moreover, it is recommended to collect more specific data on land use practices such as rotational land use practices as well as various mitigation techniques. In this context it is particularly interesting how, why and since when they are applied. In terms of the indigenous vegetation it is recommended to actually identify individual species. Furthermore, it is recommended to not only test the manual by analyzing the EA findings and giving recommendations but to take the entire EA and WAP manual into account, meaning to actually establish a watershed planning team and implement an EA and WAP in a MHP community. Only then the actual practicability of the manual can be fully certified.
Since the manual and the corresponding checklist and questionnaire were particularly developed against the backdrop of the Ethiopian environmental and climatic conditions for MHP implementation (see chapter 5.1), it should be noted that their application in other regions and/or countries might not be as fitting and comprehensive as intended.

The sustainable use of MHP plants is highly dependent on the environmental condition of the plants' catchment areas and thus on the prevailing land use, land use practices and associated degradation causes and features. The respective ecological condition of the catchments of the GIZ ECO MHP plants Gobecho I and II as well as Hagara Sodicha in the Sidama zone/SNNPR/Ethiopia was, with some exceptions, surveyed, analyzed and discussed according to the EA and WAP manual.

As illustrated in the scope of this paper, the two catchments feature both positive, but primarily negative land use practices as well as various associated degradation features to a different degree and extent. Since agriculture, pasture and forestry is the economic basis for most of the people living in the two catchments, environmental protection needs to be included in the land use in form of more appropriate land use and mitigation techniques as recommended in the scope of this study as natural conservation is not an option. The application of well adapted techniques will not only benefit the overall ecological condition and thus the economic situation in the catchments but will contribute to a sustainable use of the MHP plants.

Finally this leads to the conclusion that the EA and WAP manual developed for the GIZ ECO hydropower component includes important issues and coherences that need to be addressed and/or mitigated in order to provide for a sustainable use of not only the MHP plants Gobecho I, Gobecho II and Hagara Sodicha, but also for any other future GIZ ECO MHP development.

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Maps

Map of Ethiopia 1 : 50,000 (Ethiopian Mapping Agency), sheet 0638 B3 “Arbe Gona”, series ETH 4, edition 1 EMA 1988. Addis Ababa.

12. Annexes

Annex 1: **Environment Assessment and Watershed Action Planning manual (see enclosed document)**
Source: Meder 2011

Annex 2: **Gobecho downstream catchment: land use, degradation and mitigation techniques (see enclosed map)**
Source: Meder 2011, based on Egger 2010 and Meder 2011

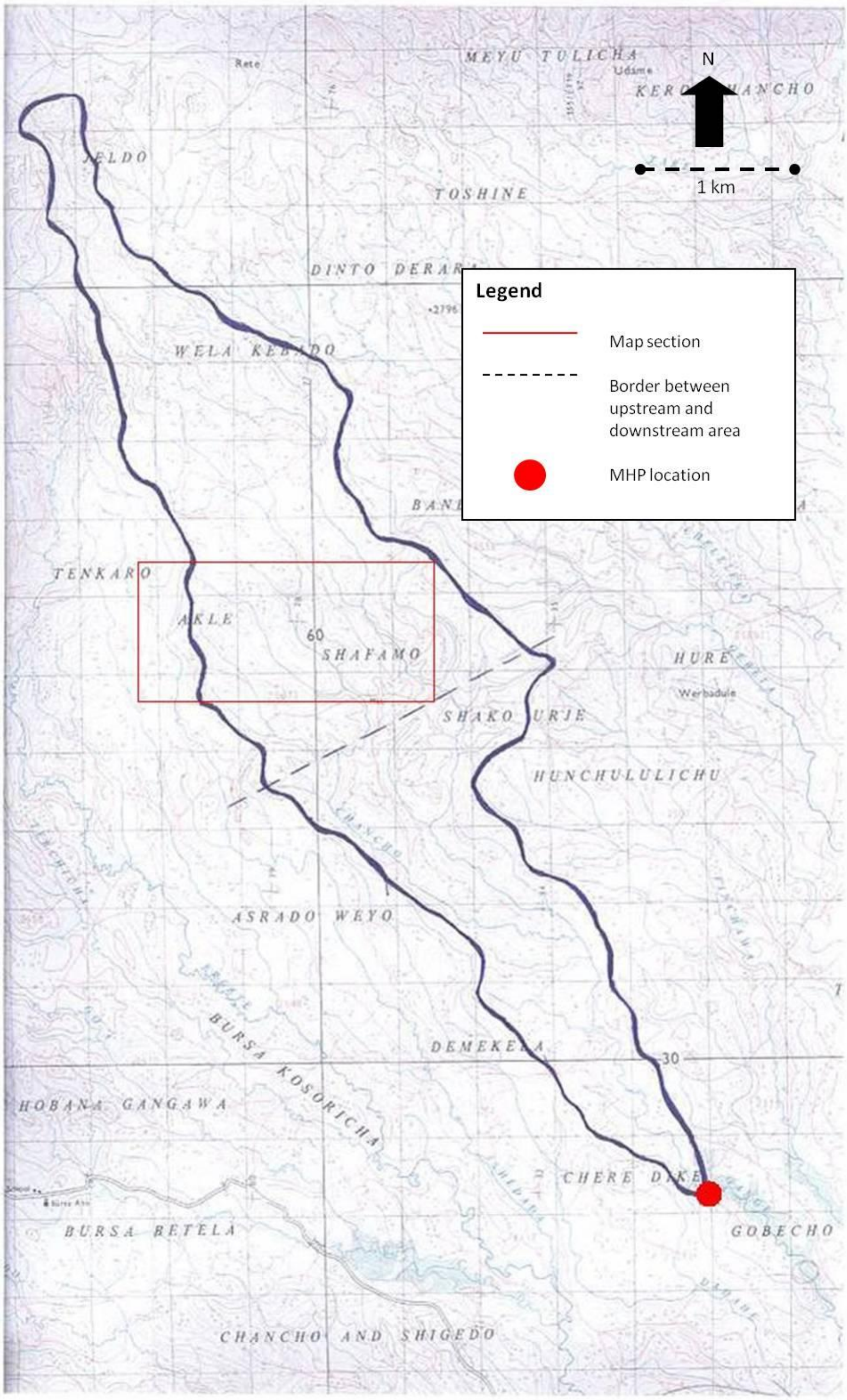
Annex 3: **Gobecho upstream catchment: land use, degradation and mitigation techniques (see enclosed map)**
Source: Meder 2011, based on Egger 2010 and Meder 2011

Annex 4: **Hagara Sodicha downstream catchment: land use, degradation and mitigation techniques (see enclosed map)**
Source: Meder 2011, based on Egger 2010 and Meder 2011

Annex 5: **Hagara Sodicha upstream catchment: land use, degradation and mitigation techniques (see enclosed map)**
Source: Meder 2011, based on Egger 2010 and Meder 2011

Annex 6: Topographic map-based watershed delineation of the Gobecho catchment. The marked map section indicates the location of Annex 7.

Source: Meder 2011, based on Map of Ethiopia 1 : 50,000 (Ethiopian Mapping Agency), sheet 0638 B3 "Arbe Gona", series ETH 4, edition 1 EMA 1988. Addis Ababa.



Annex 7: **Exemplary base map of a subdivision of the Gobecho catchment. For location of the map section, see Annex 6.**

Source: Meder 2011, based on Map of Ethiopia 1 : 50,000 (Ethiopian Mapping Agency), sheet 0638 B3 “Arbe Gona”, series ETH 4, edition 1 EMA 1988. Addis Ababa.